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AREA PRECIPITATION MEASURING INDICATOR

BY

WILLIAM G. STONE

OCTOBER 1964

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AREA PRECIPITATION MEASURING INDICATOR

by

William G. Stone

Meteorological Division
Surveillance Department

October 1964

DA Task No. IV0-25001-A-126-02

U. S. ARMY ELECTRONICS LABORATORIES
U. S. ARMY ELECTRONICS COMMAND
FORT MONMOUTH, N. J.

ABSTRACT

This is a detailed discussion of the design, development, and construction, and an evaluation of an experimental model of the Area Precipitation Measuring Indicator (APMI). This system was designed to accept video signals reflected from weather clouds through the use of Radar Sets AN/MPS-34 or AN/CPS-9; to quantize these signals into three measurements: intensity, range extent, and azimuthal extent; and to print these measurement data in alpha-numerical form on a direct-view storage tube. The APMI equipment operates in one of two basic modes: PPI and OFF CENTER. In the OFF CENTER mode, expansion of a target is permitted and a blown-up area is printed on the display.

A general description of the overall operation and capability is presented, followed by a detailed description of the theory of operation of the system.

Finally, results of the electrical test performed, future system consideration, and conclusions are presented.

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AREA PRECIPITATION MEASURING INDICATOR

INTRODUCTION

When the output of a weather radar set such as the AN/CPS-9 or AN/MPS-34 is observed on the Plan Position Indicator (PPI) and the Range Height Indicator (RHI), the observer obtains a comprehensive picture of the local weather pattern and therefore the precipitation area within several hundred miles. The observer equipped with such information as geographical location, size, and rate of movement of the storm areas is provided with a useful tool for early forecasting of local weather.

Although this information is reliable for a coarse estimate of the local weather condition, additional data such as the severity of the storm, the location of the more active cells within the cloud area, and the dimension of the cloud would be invaluable for detail weather forecasting.

It is known that rain droplets, ice particles, snowflakes, and regions having large gradients of index refractions will return detectable echoes to the radar receiver. It is appreciated, however, that the size and density and population of particles due to precipitation determine the echo power. It is believed that this echo power, if accurately determined, will add to the knowledge of cloud structure and possibly become an aid for more comprehensive weather forecasting.

This report describes the Area Precipitation Measuring Indicator (APMI), a digital equipment which, when used with either Radar Set AN/CPS-9 or AN/MPS-34, will provide a quantitative measurement of cloud intensity and dimension. These values are printed (in stored real time) in numerical form on a cathode-ray direct-view storage tube display. This equipment can be used for atmospheric investigation in several areas of interest such as rainfall rate-radar intensity and correlation studies; severe storm analysis including hurricanes and tornadoes, and nuclear-blast studies.

The Area Precipitation Measuring Indicator (APMI) program was initiated with award of contract on 1 Jul 62 to Motorola, Inc., under Contract DA 36-039 SC-90825, in accordance with Technical Requirements No. SCL-5857 (amended 13 Oct 62).

DISCUSSION

The Area Precipitation Measuring Indicator (APMI), Fig. 1, is basically a digital computer and a storage display unit whose operation is dependent on meteorological data in the form of radar signals from either Radar Set AN/CPS-9 or AN/MPS-34. This equipment measures the echo intensity from clouds or precipitation in addition to the dimensional extent of the reflecting mass, quantizes these signals, and displays the data in alpha-numerical form on a 10-inch direct-view storage tube. Figure 2 is a block diagram of the complete system.
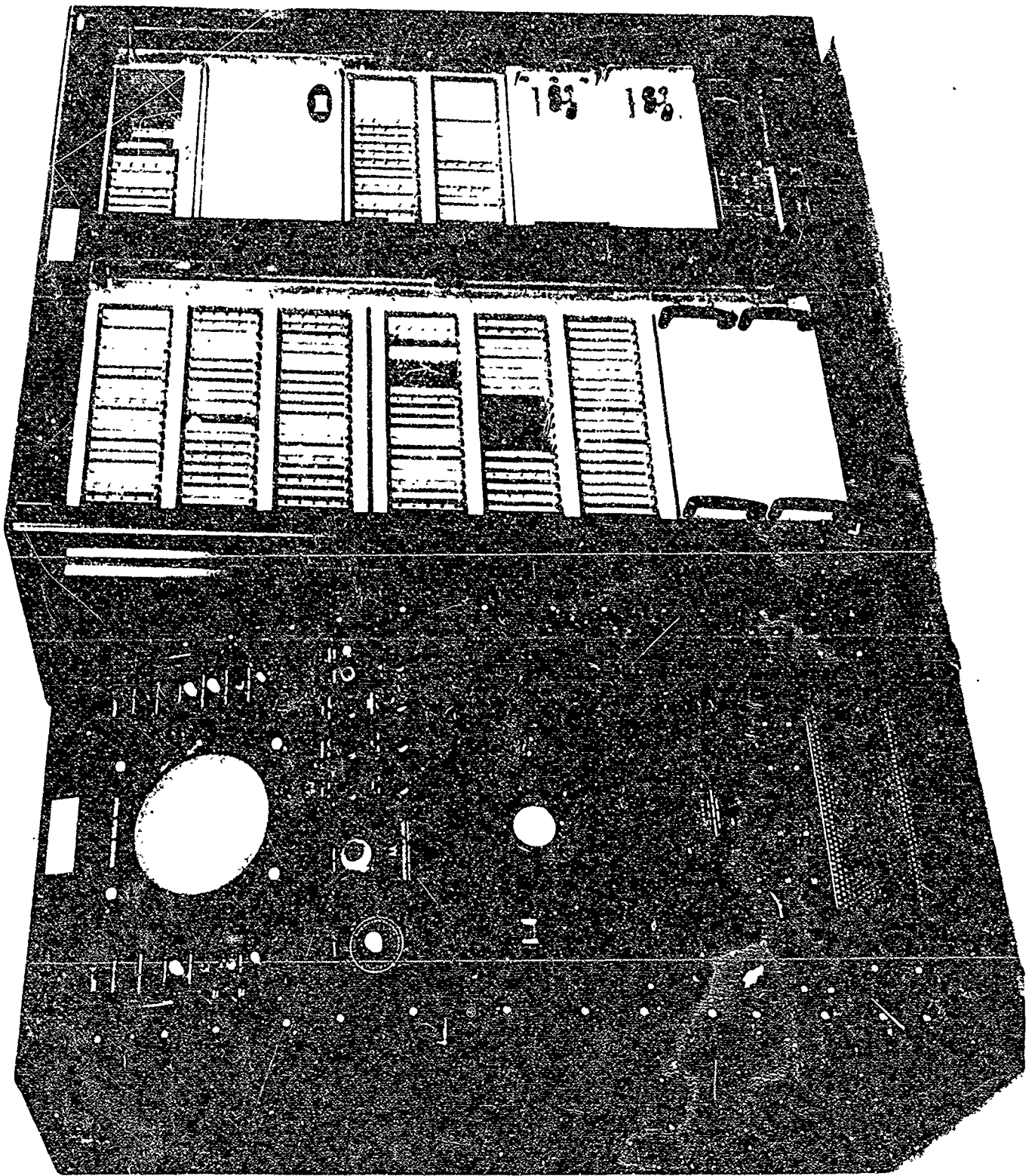
Fig. 1. Area Precipitation Measuring Indicator

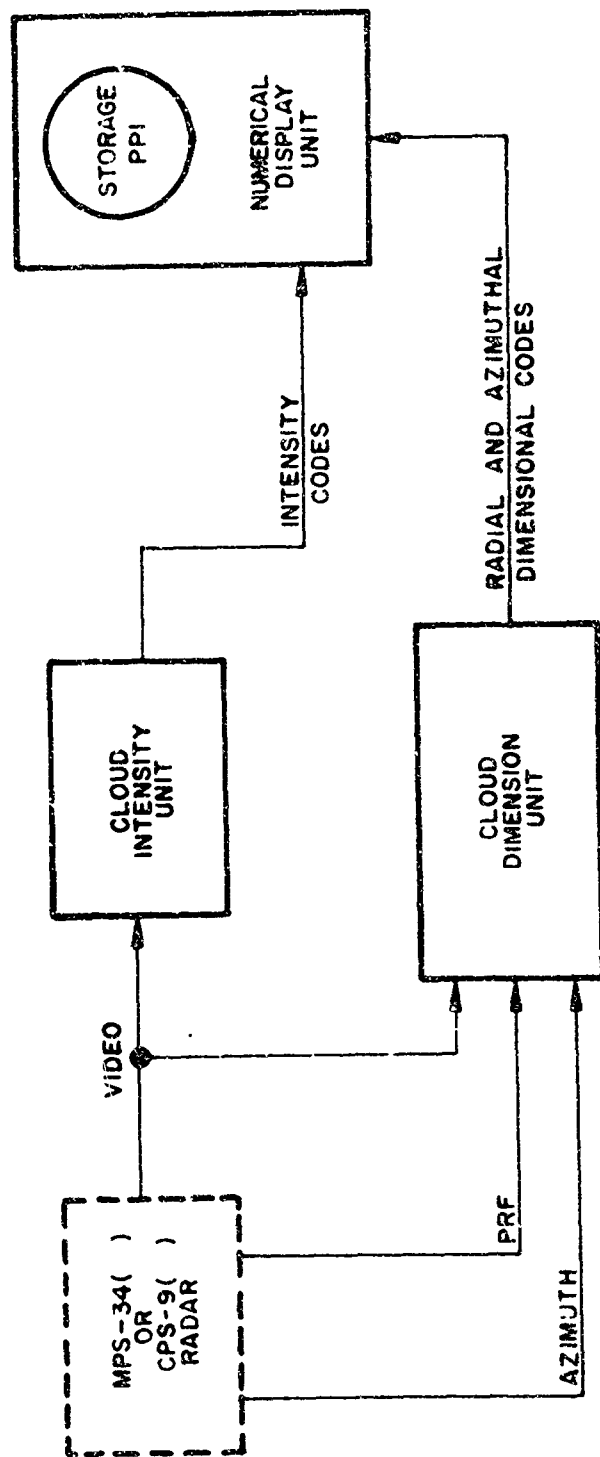Fig. 1. Area Precipitation Measuring Indicator

Fig. 2. Block Diagram, Area Precipitation Measuring Indicator

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The APMI operates in two basic modes. In one mode the display is arranged in a manner similar to that of a conventional PPI display except that the data to be displayed are in alpha-numerical form. These characters, representing cloud intensity and dimensional measurements, are arranged in such a manner that they occupy a location in the display as the cloud or any reflecting areas are distributed around a radar site. The PPI type of display provides a nondistorted view of the actual reflecting area shape.

The second display method is the OFF CENTER mode. This display mode is termed a "B" scan type of presentation. The "B" scan presentation permits the operator to select the area of interest in the radar field of view and displays only that region selected, thereby vastly increasing the display resolution. Of course this type of display, a wedge-shaped section of radar space, is mapped into a rectangular display matrix. As a result, a certain amount of distortion is introduced such that although reflectors are displayed in their relative position with respect to other clouds in the displayed area, the size of clouds displayed becomes a function of radar range. The distortion introduced is not considered a problem because in this mode the operator wishes to study the detail structure of the cloud and not its shape or size.

The APMI was designed to handle a vast amount of weather data in a short period of time. The computing process is continuous and often repetitive, thereby resulting in thousands of arithmetic operations in computing cloud data derived from the radar set. The result is that the information displayed relieves the operator of interpreting the many different classes of received data. Because there are radar operators with varying degrees of operating skill, this interpretation of data from radar PPI is often in disagreement.

The APMI system, by virtue of displaying numerical values corresponding to echo power, eliminates the degree of judgments normally reserved to the operators. Therefore, the displayed data are equally weighted regardless of the operator's skill. Also, because of the high-speed operation of the APMI and its area-sampling techniques, small-gain data and real-time information are obtainable.

In computing cloud extent, the APMI must first determine whether the incoming radar signals are returns from weather clouds, noise, or other types of targets. The requirement is for a detection circuit that continuously examines all radar signals and determines only those signals returning from weather clouds. Obviously such a circuit must be simple, economical, and possess a high probability of weather cloud detection under all environmental conditions. This system employs an automatic target-detection circuit that has a signal-to-noise ratio of approximately 6 to 12 db. Although this detector does not eliminate all false alarm signals, it does distinguish between aircraft, noise, or any point source target simply on the basis of their extent in the radial and azimuthal dimensions.

The received signal power is measured with little difficulty and correlated with cloud detection decision, giving a measure of the cloud intensity. The radial dimension or extent of the cloud in range, measured during a single pretriggered sweep period, is performed by noting the time or range in which the cloud is initially detected, and counting range increments as long as the cloud is continuously detected.

The measurement of the cloud azimuthal (arc length) at any one or a number of ranges over which the cloud is continuous is performed by a discontinuous memory function which keeps track of the cloud azimuth increments. This memory function is supplied by a number of counter channels, each associated with a particular range.

The data are presented numerically in plan-position form, temporarily stored or regenerated for visual observation. The temporary storage allows time for cloud assessment or photographing for later detail analysis. The PPI form in which numerical data are displayed provides the necessary situation for correlation with radar video PPI display. The storage tube used in the display has an overall diameter of 10 inches; however, the usable diameter is approximately 8 inches. The numerical character height is 1/16 inch, with center-to-center spacing of 3/32 inch (approximately 1 inch). The scale factor of the display is a function of the dimension assigned to the characters. The cloud intensity measurement figures are indicated by the printed 1's (corresponding to a single digit, 0 to 9, intensity measurement). The radial dimension values are represented by 3-digit RNNN, with R identifying the dimension. The ANN characters correspond to 2-digit azimuthal dimension values.

The radial values are always printed at the top or outer fringe of the cloud area, and the azimuthal values are always printed to the right at the outer fringe of the cloud area.

An X-Y storage and deflection system is employed to accomplish the required average-time display. The input data are resolved prior to storage on a real-time basis and then displayed later as timing permits. The X-Y format facilitates the presentation of erect characters on the display and obviates the need for any increased researching function.

DESCRIPTION

The Area Precipitation Measurement Indicator (APMI) accepts raw radar data from either Radar Set AN/MPS-34 or Radar Set AN/CPS-9. It then determines both the amplitudes of these signals (from a preset reference signal) and the radial and azimuthal extent of the cloud. These data are converted into a binary code for easy handling by the machine, and then displayed in numerical form on a 10-inch storage CRT.

The display format gives the unit square intensities within the cloud area. These intensities values are averages extending over 1.6 miles to 28.8 miles, depending on the desired range setting of the radar set (25 to 450 miles). (See Table 1, Display Element Size, with radar range scale setting.)

The range and azimuth extent measurement values are printed (in miles) on the fringe of the cloud image. The range measurements are printed on the display as 3-digit words--an R followed by 2 decimal digits--and are measurements of the range extent from 0 to 99 miles in 1-mile increments.

The azimuth-extent measurements are printed as 3-character words--the letter A followed by a 2-digit number--and are measurements of the azimuthal

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Table I. Display Element Size

RANGE SCALE (miles)	PRF	
	186	931
25	0.8 mi x 2.9°	0.8 mi x 1.1°
75	1.6 mi x 1.6°	1.6 mi x 0.58°
200	3.2 mi x 1.6°	
450	4.8 mi x 1.6°	

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extent of a cloud over two radii or an arc length of 99 miles in 1-mile increments. A cloud of extent greater than two radii, or an arc length greater than 99 miles, will cause the formation of a wrong product and therefore result in erroneous reading.

Automatic Cloud Measuring Indicator

The three units comprising the automatic cloud measurement indicator as shown in Fig. 3 are:

Cloud intensity measurement unit

Cloud dimension measurement unit

Display unit, incorporating a storage type of cathode-ray tube for presentation of the numerical cloud measurement data in plan-position (PPI) form.

The major functions performed by each unit are listed below:

Cloud Intensity Unit

Video signal filtering

Multilevel video threshold detection

Intensity level encoding

Manual control of video gain and range attenuation compensation

Sweep-to-sweep averaging process

Cloud Dimension Unit

Radar range encoding

Radar azimuth conversion--azimuth sine and cosine encoding, and azimuth pulse generation

Cloud detection on a sweep-by-sweep basis

Cloud range extent measurement and gating function

Cloud azimuth extent measurement and gating function

Coding programs for measurements of cloud intensity, azimuthal and radial dimension, as a function of radar range and pre-triggered sweeps

Conversion of radar range--azimuth coordinates to X-Y coordinate location of cloud-measurement data

Range shifting and scale expansion functions

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FIGURE 3 - AUTOMATIC CLOUD MEASURING INDICATOR SYSTEM BLOCK DIAGRAM

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Numerical Display Unit

Cloud measurement data buffer storage

Buffer storage programming for write-in data location and readout data sequencing

Alpha-numeric character generation

X-Y digital coordinate to analog voltage and sweep voltage generation

Manual switching and control functions for operation of PPI storage tube numerical display

Intermediate Frequency Amplifier

The radar receiver was modified to incorporate a line driver to couple the 30-mc IF from the second stage IF amplifier to the input of the APMI via a 50-ohm coaxial cable.

The 30-mc IF amplifier and detector strip in the APMI receives the signals from the radar IF amplifier and raises the output to a 1-volt level. The APMI IF amplifier gain is electrically controlled by one of the two switch-selected normalization functions. The functions are generated by a function generator consisting basically of integrating capacitor driven by range-gated current sources. The operation of these circuits is explained under "Range Normalization," below. The IF amplifier is designed to accept an extremely wide range of input signals. This is accomplished by the use of circuitry that produces a logarithmic amplitude response. In this way the output dynamic range is compressed while the amplitude relationship between signals is preserved.

The overall gain is 90 db. The overall dynamic range is 80 db, being linear for the first 10 db and logarithmic over the remaining 70 db. The passband is two megacycles.

The range normalization voltage is applied to the sensitivity time control (STC) input, with -12 volts corresponding to minimum gain, and zero volts corresponding to maximum gain. Amplified gain is controlled prior to any logging action. A 2-decade line attenuator is inserted in the input line to allow for the attenuation of very large signals.

The one-stage video amplifier, an integrator amplifier, and an emitter follower stage are driven by the IF amplifier, with the emitter follower having sufficient impedance to drive the intensity encoder and range detector circuitry.

The video amplifier has a gain of 20 db, which raises the signal from the IF amplifier to 10 volts for the intensity-measurement circuitry. Direct current restoration is provided to clamp the video wave form prior to amplitude measurement.

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To remove the effect of high-frequency spikes, smoothing circuits are provided to the input of the video amplifier.

Range Normalization

The sensitivity time control (STC) changes the gain of the IF amplifier as a function of radar range to compensate for the effect of propagation attenuation (Fig. 4). An analog function generator is utilized to provide the operations required to change the IF gain in any manner desirable.

The range normalization circuitry consists of 8 NOR circuits, driven by the output of the 1-mile range counter, which generates -100-volt gates at different range intervals. Normalization starts at range zero and ends at range 256 miles, after which the IF strip is at maximum gain. The gates are of shorter duration in the region of greater curvature of the analog normalization function.

The functions are generated by a capacitor which integrates values of current supplied by the 8 gates. The capacitor is initially charged to approximately +2 volts by the pulse rate frequency reset signal. The signal occurs during the dead time preceding each radar trigger. The capacitor then discharges at a rate controlled by the setting of the potentiometer associated with each gate output.

Two sets of potentiometers are provided so that an R^2/R^4 function can be selected by means of the R^2/R^4 range relay which, in turn, is controlled by the control panel R^2/R^4 manual switch.

A single potentiometer which returns to +24 volts supplies a constant charging current to the   capacitor to compensate for leakage losses. A diode is connected across the   egrating capacitor to prevent voltage across the capacitor from going ne   .e.

The capacitor voltage is coupled to the input of an operational amplifier through an emitter follower stage. The operational amplifier amplifies and inverts the normalization function. The amplifier output is connected to the STC input of the IF amplifier.

Intensity Measurement

The ten-level intensity circuit is an analog-to-digital encoder that determines the peak amplitude of the input video signal. This peak amplitude is thus converted to a BCD code and on command transferred to an adder counter in the integrity integrator circuit. The encoder is then reset so as to ready it for the next set of input signals.

The intensity level encoder consists of 10 voltage comparators, reference voltage, a logic circuit to determine the highest of the 10 intensity levels, a decimal-to-binary encoder, and associated control circuit.

The intensity level encoder (Fig. 5) functions as follows: The center tap of each potentiometer is extended to the set input of each flip-flop.
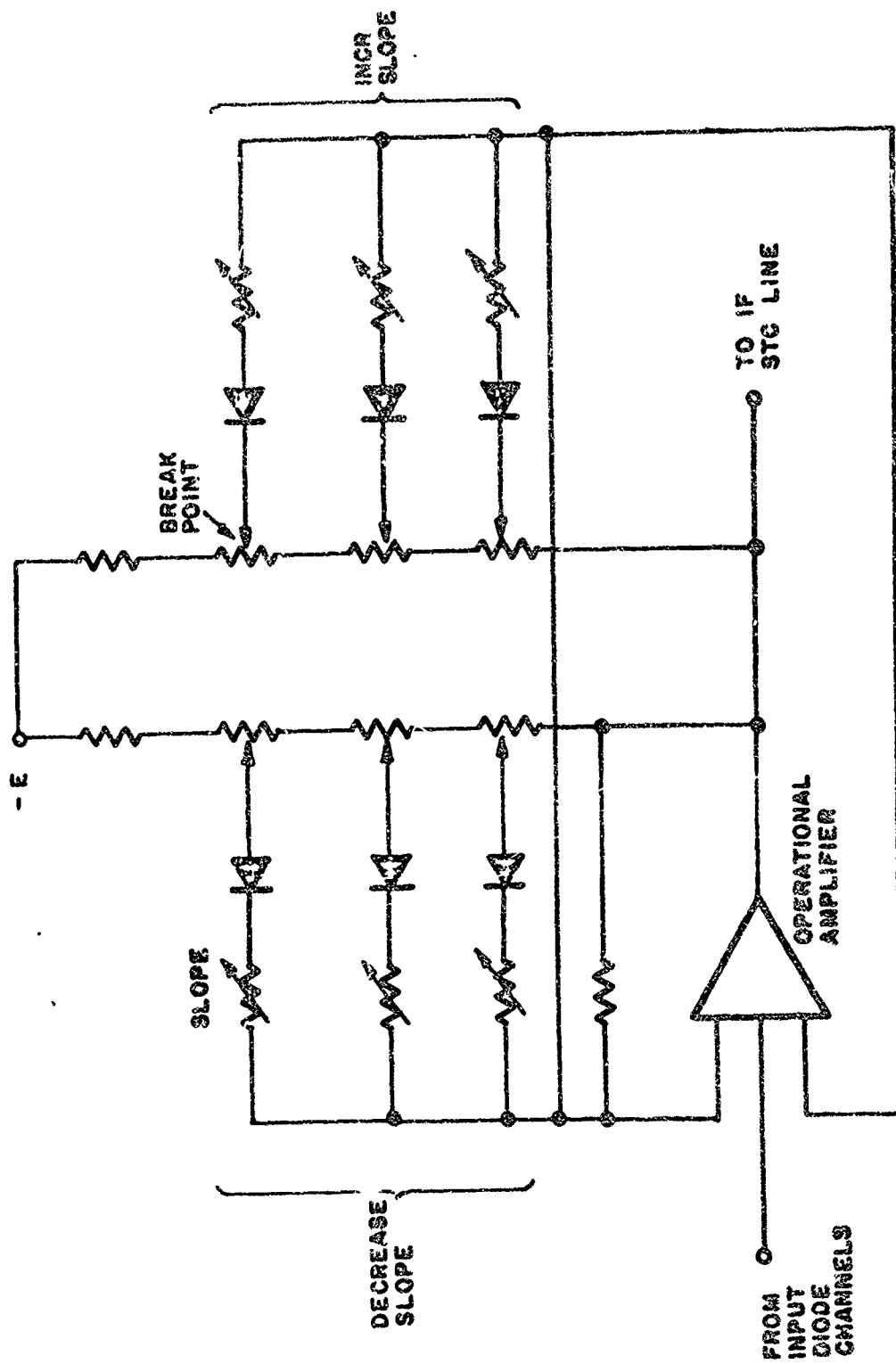
10

FIGURE 4 — STC DRIVE AMPLIFIER AND LINEARIZING NETWORK
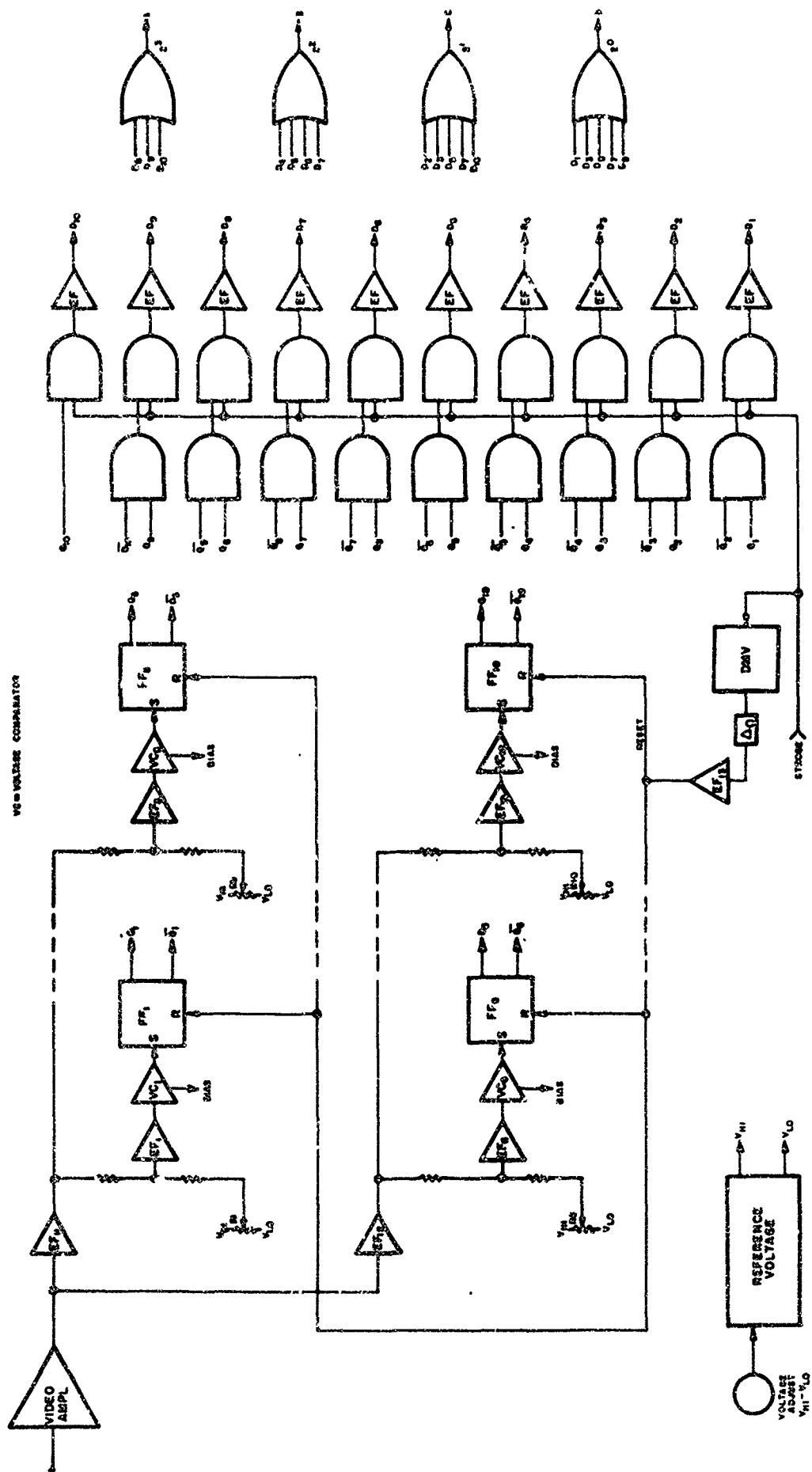
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FIGURE 5 – INTENSITY LEVEL ENCODER

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One end of the potentiometer is common and it is to the points that the video pulses are applied. The setting of the potentiometer controls the input current and hence the triggering level to each flip-flop. Each flip-flop has an accompanying indicator light and may be used as an indication of the intensity level of the input signal merely by counting the number of ON lights that are glowing. The neon indicators are also used for calibrating the threshold level.

The decimal-to-binary conversion is done by the logic circuits that follow. The output of the level-detecting flip-flop is extended to ten inputs and gates which determine the logical product between the "1" output of a flip-flop and the "0" output of the next higher level flip-flop, representing the highest intensity level applied. The output of the AND gates is amplified and inverted and applied to four NOR gates via emitter follower, where binary conversion is performed.

Intensity Integrator

The intensity integrator circuit of the APMI directly controls all encoded intensity measurements from the time of measurement to time of display. Its function is to sum and divide intensity measurements (signal averaging), range, azimuth extent measurements, decisions concerning accepting of new data or printing of quantized data, data priority, and character generator print-out control.

A small portion of the buffer memory is used for the averaging of intensity measurement samples. Thirty-two words of memory are used for this operation. Averaging is accomplished by adding the encoded intensity values for 8 consecutive sweeps when using the low pulse rate frequency of 186 cps and 16 consecutive sweeps when using the high prf of 931 cps. This averaging process has the effect of smoothing out the fluctuations that are inherent in video return from clouds.

The adder used to accumulate intensity measurements is comprised of eight bits, and functions according to the integration timing chart for integration mode of operation (Fig. 6). The adder is readied when a reset command pulse is received from the memory timing circuit and reset to zero. An ADD transfer pulse then transfers information from the four-bit intensity level encoder into the ADDER. Simultaneously, an "unload" sync pulse transfers previously stored data from the memory information register to the input of the eight-bit parallel adder. Since no data were stored in the memory information register at the initial processing time, the first sum brought from memory will be zero.

This sum is then added to coded intensity data previously held in the adder by an ADD strobed command pulse. When the addition has been completed, the sum will appear both at the output of the ADDER and the inputs of OR gates in complement form. The sum is gated through the OR gates by an integrating pulse via inverting amplifier and applied to gating logic circuits. All data such as intensity, range, and azimuth must pass through these circuits before going to memory. A command load sync and MR strobe pulses pass the intensity sum to the integration portion of the memory. The cycle

Fig. 6 — Integrate Timing

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

X₂ Y₂ → Address Source
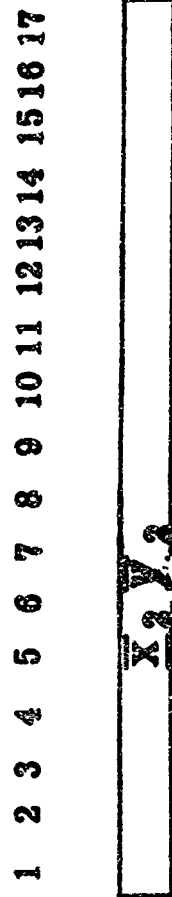
Adder
Reset

A. R. Strobe
Unload Sync,
Add Transfer

Add Strobe

Load Sync
M. R. Strobe

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repeats again, with the adder reset pulse setting the ADDER to zero, the ADD pulse setting into the adder another four-bit binary coded intensity word, the unload sync pulse bringing from memory to the input of the adder the intensity sum previously stored and the load sync command that writes the new intensity sum back into the integration portion of the memory for another addition process to start. For the 931 PPS (high pulse rate), the cycle repeats 16 times; for the 186 PPS (low pulse rate), the cycle repeats eight times. At the end of the sampling time, the accumulated intensity sum is divided by the number of samples taken and then written back into the proper location in the display portion of the memory.

NOTE: A word contains eight bits (0 through 7); the 2nd and 3rd are not used. The 4th, 5th, 6th, and 7th bits contain the intensity, or dimension, information. The zero and one bits are identification bits. When the zero (print ID bit) bit is set to its true state, the word of which it is a part has been printed. When the one bit has been set to its true state, the word of which it is a part contains dimension data. This bit is called the dimension ID bit and is used to inhibit any new dimension data from entering the memory if old data have been previously stored.

On command of unload sync and AR strobe pulses (Fig. 7), the word previously stored is brought out from the display portion of memory (memory output) and gated to the special gating logic cards. The two information bits (0 and 1) from memory are applied to an OR gate. If both of these bits are zero at the time data are sampled, the AND gate remains closed and the inhibiting flip-flop that follows remains reset. A reset condition is an indication that the word brought from memory has not been printed and does not contain dimension data, and calls for dumping this word and rewriting a new word in its place. The accumulated sum from the integration portion of the memory is transferred by the unload sync and AR strobe at the 6th count of the memory timing. The 4th, 5th, 6th, and 7th bits then are gated through special gating logic cards to the display portion of the memory by load sync strobe and MR strobe command pulse at the count of thirteen. It should be noted that the four least significant bit has been discarded. This, in effect, has shifted the decimal point four bits, thereby a division of 16 for the 931 PRF (high). In the 186 PRF (low), the three least significant bit has been discarded, thereby a division of eight.

In the case where either the Print ID or Dimension ID bit was a "1," indicating that either data at the time of sample has not printed or the word contains dimensional data, the inhibit flip-flop would have set to the one position, thereby inhibiting the unload sync and AR strobe pulses at the count of eight and the MR strobe at the count of 13. Consequently, the word transferred from memory is not passed on to the display portion of the memory as was the case mentioned above; the accumulated sum is dumped and the dimensional data are rewritten back into the memory at the count of 13. This condition means that printed data and previously stored dimension data have priority over new intensity or new dimension data.

As mentioned above, the intensity integrator unit also controls processed dimensional data. Similarly, the intensity data, range, and azimuth data are gated from their respective BCD counters to the display portion of

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Fig. 7. Store Intensity Timing

memory via the special gating logic cards. The dimensional data appear as three words: one word for identifying letter A (azimuth) or R (range), one word for the ten number, and one word for the unit number. These words are gated to memory, one word at a time. This sequential operation is accomplished by lines to the gate circuits marked Θ, R, A, B, and C. The Θ and R lines select either azimuth or range data, the command being generated in the dimension code receiver. The A, B, and C lines select each word of the dimension (azimuth range), one word at a time.

Figure 8 is a timing diagram of the commands that control the storing of dimension data. At the count of two of the memory timing cycle, a word is transferred from the display portion of the memory by the unload sync and AR strobe commands. At a count of six, the print ID bit and dimension ID bit are sampled. If both bits are zero, the word transferred from memory is not dimensional data and has not been printed. At a count of eight, the load sync and MR strobe command pulse gate the new dimension data to memory, one word at a time. Simultaneously, at the count of eight, an advance pulse is generated which activates a shift register which shifts (A, B, and C command in the dimension code receiver) from the A command to the B command. This action is repeated until all three words are transferred into memory.

This unit, in addition to handling the above function, also handles words from the display portion of memory during the print mode. These words, one at a time, are decoded, and thereby generate the proper command for the character generator. In this case the word that is brought from memory to be printed--the 4, 5, 6, and 7 bits--is applied to the appropriate terminals of a flip-flop register. The output of this register is then applied to a decoding network which energizes the proper line of the character generator.

Mode Programmer

The mode programmer generates the timing of the integrate, store, and print sequence.

The integrate interval consists of a time span of 8, 16, or 32 PRF sweeps. The integrated time interval is a function of the range and PRF setting. The time during each integrate interval is utilized for the sweep-to-sweep averaging of the intensity values.

The store interval immediately follows the integrate interval and is divided into two parts: store intensity and store dimension. The store interval lasts for only one sweep time of PRF period, regardless of range; however, the length of time for the interval is a function of PRF. The store interval is used for the transfer of average intensity values from the integration portion of the memory to the display portion of the memory and also for the storing of any range or azimuth values.

The print interval follows the store interval and lasts for one sweep period. The print interval is a function of PRF and is independent of range. During this interval, both intensity and dimension values are transferred from the display portion of the memory and are printed on the display storage cathode-ray tube. Figure 9 depicts the functional operation and logical equations utilized here to perform these functions.

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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

X₄ Y₄   X₄ Y₄ ← Address Source

A. R. Strobe
Unload Sync

Sample Data

Advance
Load Sync
M. R. Strobe

STOP Clock   If no dimension data has been
                    stored or data has not been printed.

                    Print ID Bit + DIM ID Bit = 0

Load Sync   If dimension data has been stored
                    or data has been printed.

STOP Clock   Print ID Bit + DIM ID Bit = 1

Figure 5 – Store Dimension Timing

IF pulses

0   5   10   15   20   25   30

Integrate

HI PRF
25 Mile Range   Store   Print

Integrate

HI PRF
75, 200, 450 Mile Range   Store   Print

Integrate

LO PRF
25 Mile Range   Store   Print

Integrate

LO PRF
75, 200, 450
Mile Range   Store   Print

LOGICAL EQUATIONS

$$\text{Integrate} = (r^2 \cdot 25 \cdot HI) + (\overline{EF} \cdot 25 \cdot HI) + (\overline{EF} \cdot 25 \cdot LO) + (\overline{DEF} \cdot 25 \cdot LO)$$

$$\text{Store} = (\overline{ABCDEF} \cdot 25 \cdot HI) + (\overline{ABCDEF} \cdot 25 \cdot HI) + (ABCDEF \cdot 25 \cdot LO) + (ABCDEF \cdot 25 \cdot LO)$$

$$\text{Print} = (\overline{ABCDEF} \cdot 25 \cdot HI) + (\overline{ABCDEF} \cdot 25 \cdot HI) + (ABCDEF \cdot 25 \cdot LO) + (ABCDEF \cdot 25 \cdot LO)$$
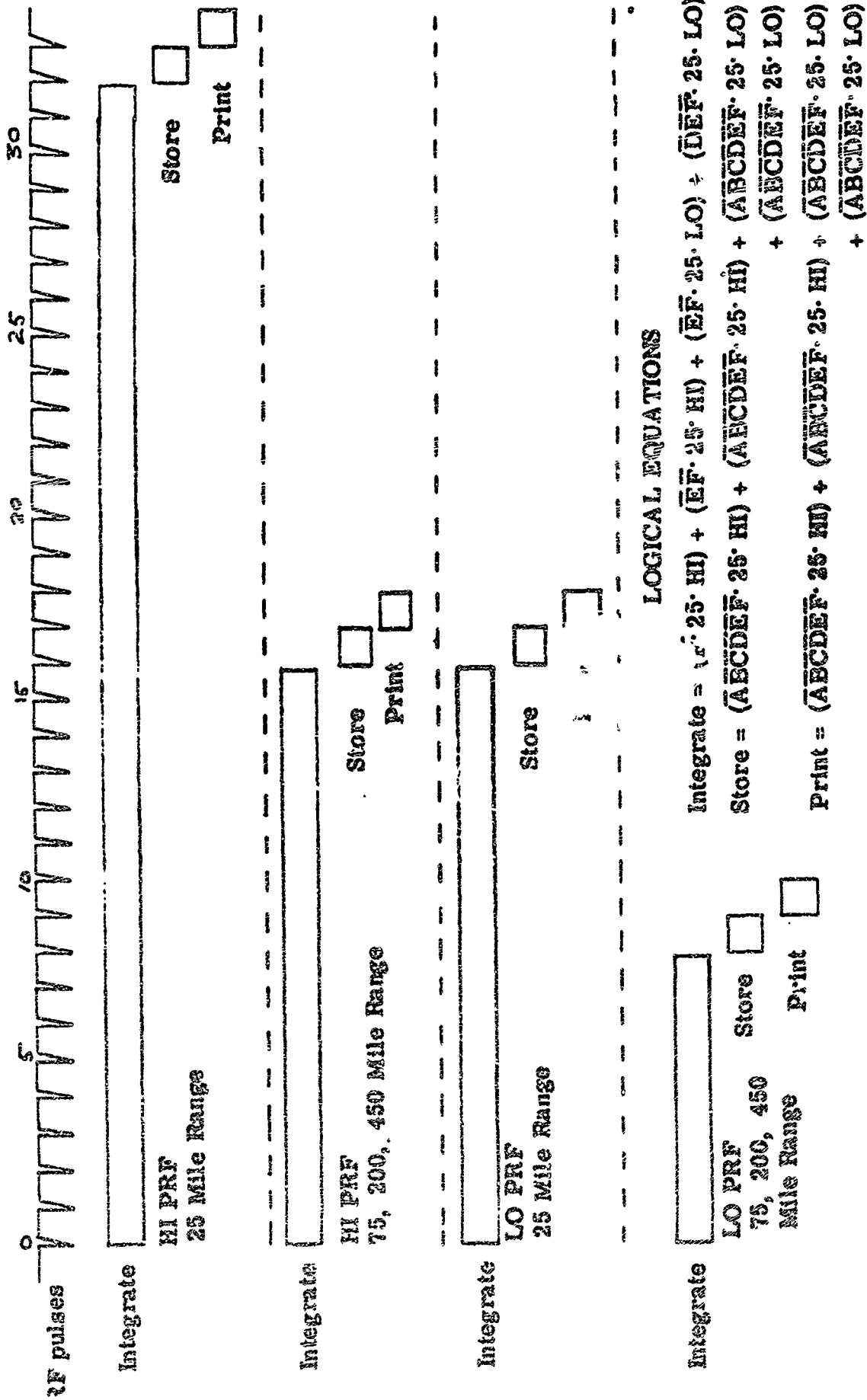
Figure 9 — Mode Programmer Timing and Logic Equations

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The function of the mode programmer (Fig. 10) is as follows: The circuitry is divided into three sections: control circuitry, counting flip-flops, and decoding gates. The operation starts with the receipt of a pulse, a command pulse, from the azimuth control circuitry located on the servo deck. This pulse occurs once at the beginning of each antenna revolution. This command pulse triggers a half-second delay flip-flop whose feeding edge in turn triggers a 20-microsecond flip-flop. The outputs of the latter are utilized to erase previously displayed data, to reset the memory, and reset various circuits throughout the equipment. The original half-second delay was necessarily made long so as to permit all reset commands to be applied and propagated through all circuits in preparation for the following signal-processing interval. The delay output pulse of this flip-flop is extended to the set input of the "start process" flip-flop. When the next PRF pulse occurs, the flip-flop goes to its reset conditions and a "start process" command pulse is generated. This "start process" pulse sets the "start count" flip-flop, which remains until the antenna has completed a revolution.

The "1" output of the start-count flip-flop is extended to an AND gate which gates PRF pulses to a six-bit counter. The cycle repeats again at the beginning of each antenna revolution.
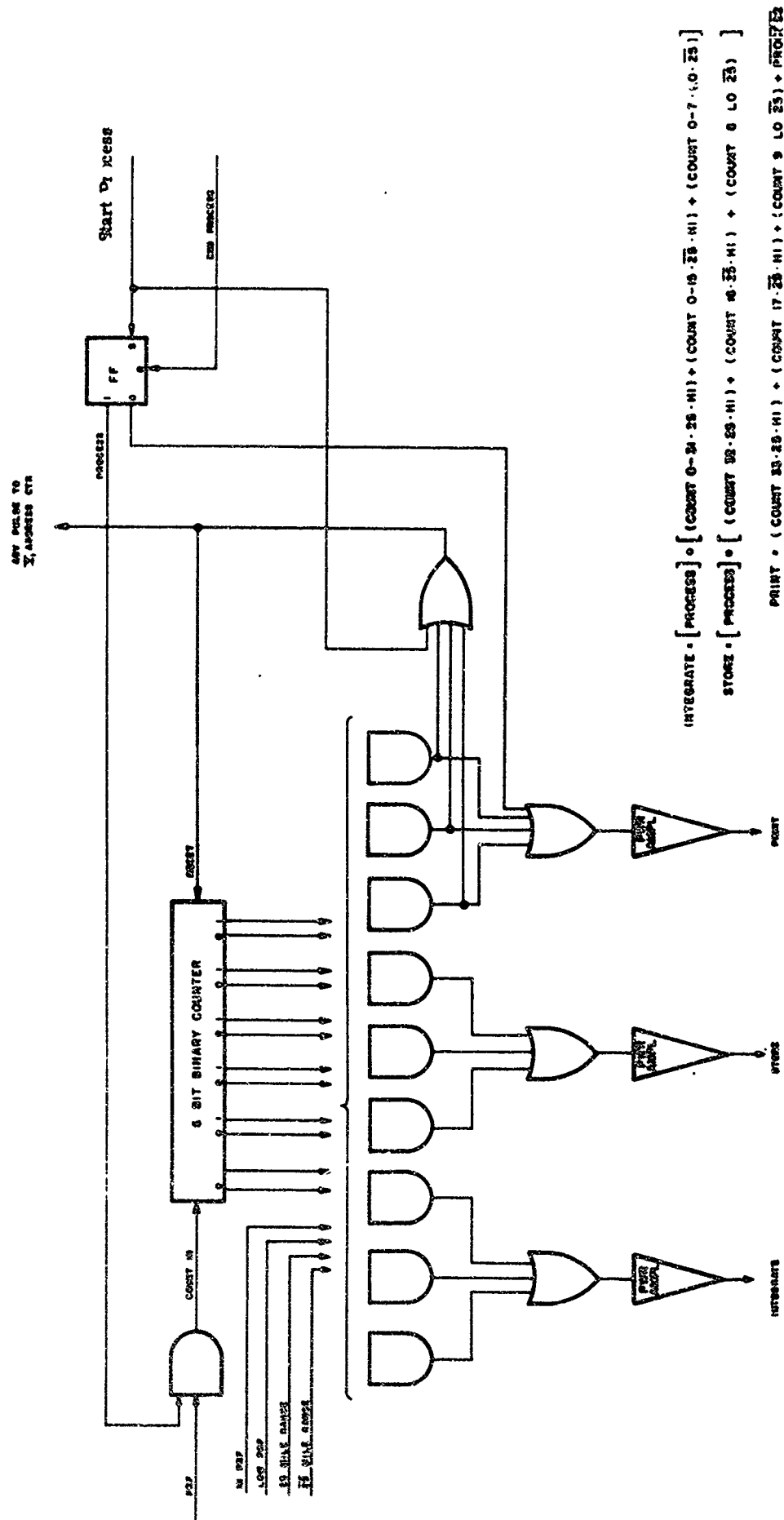
The six-bit counter counts PRF pulses in binary code. The outputs of this counter, both true and complemented, are amplified and go to decoding gates. The three sequencing signals (integrate, store, and print), in their proper position and correct time span, appear at the outputs of the decoding gate.

Although not shown, when the end of the print interval is reached, a 5-microsecond delay flip-flop is triggered by the print signal. The output of this flip-flop is amplified and used to reset the six-bit counter, whereby the counting and decoding begin again. The initial operation cycle is also reset at the beginning of each antenna revolution by the "start process" pulse. This is to insure that the first integrate interval begins initially at the start of an antenna revolution. The "start count" flip-flop is reset at the occurrence of the "Master Reset" pulse.

The "store intensity" circuit operates in such a manner that an AND gate is enabled whenever the equipment is not in the store-dimension portion of the store interval. A double inverter provides a true and complemented "store intensity" signal.

Azimuth Input Circuitry

The azimuth input circuitry (see Fig. 11) functions as follows: The stator leads of the azimuth synchro transmitter, located in the radar set AN/MPS-34 or AN/CPS-9, are extended to the APMI and are extended to the rotor of the synchro differential generator. The shaft of this generator extends through the control panel of the display unit and permits the entry of desired bearing when operating in the "Off Center" mode. The differential stator winding is extended to the synchro-control transformer located on the servo deck. The error voltage that is generated by this transformer causes

FIGURE 10 - MODE PROGRAMMER

$\text{INTEGRATE} = [\text{PROCESS}] \cdot [(\text{COUNT } 0-31 \cdot 25 \cdot \text{HI}) + (\text{COUNT } 0-15 \cdot \overline{25} \cdot \text{HI}) + (\text{COUNT } 0-7 \cdot (0 \cdot \overline{25})]$

$\text{STORE} = [\overline{\text{PROCESS}}] \cdot [(\text{COUNT } 18 \cdot 23 \cdot \text{HI}) + (\text{COUNT } 16 \cdot \overline{23} \cdot \text{HI}) + (\text{COUNT } 8 \cdot \text{LO } \overline{23})]$

$\text{PRINT} = (\text{COUNT } 33 \cdot 25 \cdot \text{HI}) + (\text{COUNT } 17 \cdot \overline{25} \cdot \text{HI}) + (\text{COUNT } 9 \cdot \text{LO } \overline{25}) + \overline{\text{PROCESS}}$
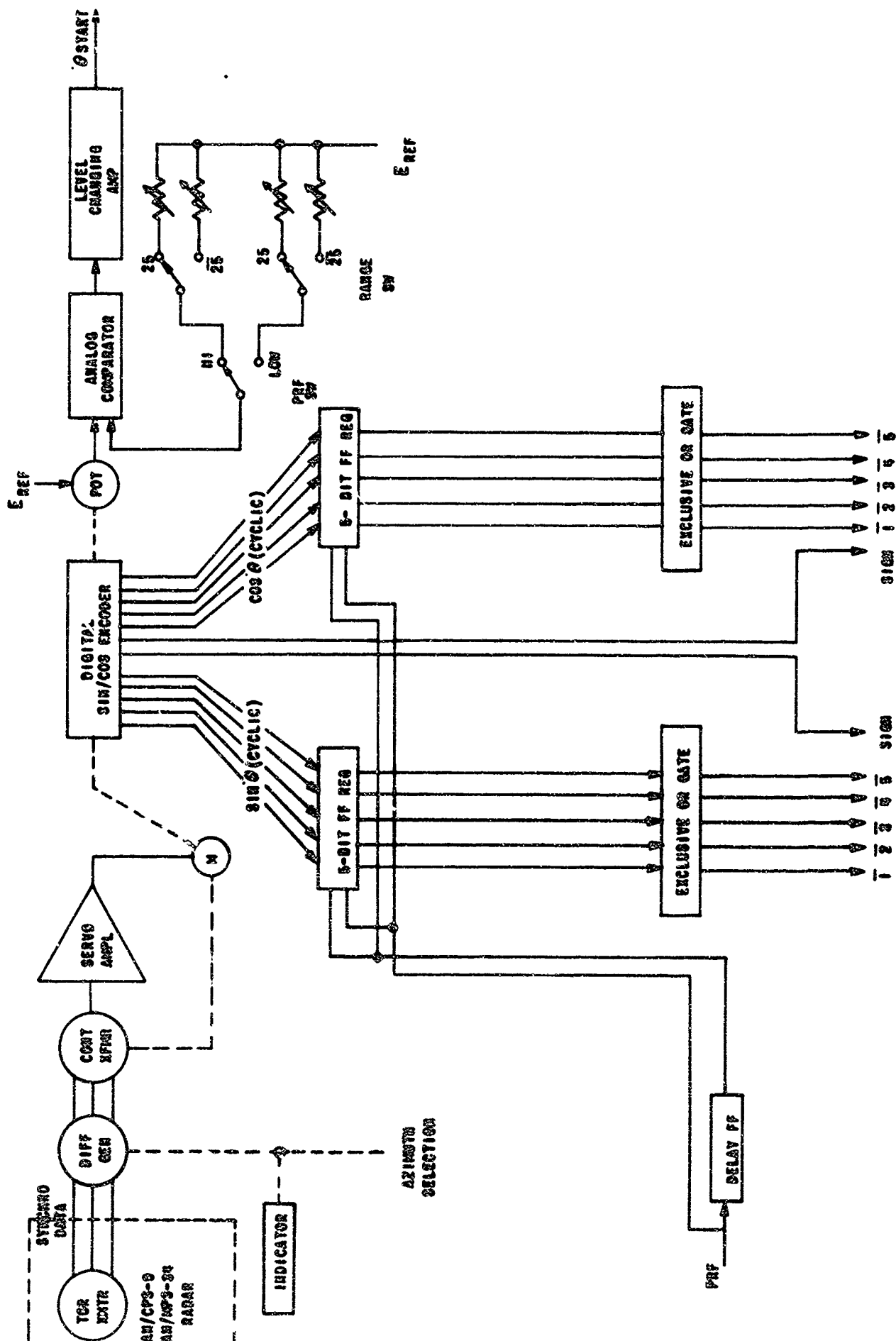
FIG. 11   AZIMUTH INPUT CIRCUITRY

the servo motor to drive the rotor of the control transformer to the null position. The control transformer, amplifier, and servo motor comprise a simple servo follower.

A digital sin/cos encoder and a continuously rotatable precision potentiometer are geared to the shaft of the servo motor. The sin/cos potentiometer converts the shaft angle to sine cosine functions and produces these functions in the form of a 7-bit binary code. A sine bit is included in the encoder and produces the positive and negative values of the sine and cosine functions. Since the 7-bit gray code is weighted and unsuitable for arithmetic operations, it is necessary to convert the output of this decoder to a 1-2-4-8 binary code.

The gray to binary converter consists of the following: A 5-bit flip-flop register; five stages of exclusive OR gates, with a true and a complemented output; and a delay flip-flop used to generate the necessary control pulses. An identical circuitry exists for the cosine conversions except for the delay flip-flop, which is common to both circuits.

The gray coded output is extended to the "Set" input of the flip-flop register. The register is first reset by the PRF, readying it for code conversion. The output of delay flip-flop, which is also triggered by the PRF, returns the flip-flop register to its true state. This action permits the gray code on the input lines to enter the register.

The flip-flop register holds this code for one PRF interval while the exclusive OR gates perform the conversion to natural binary code. The time delay between the time the code enters the register to the conversion to natural binary code is approximately 70 microseconds. This is then transferred to the coordinate converters on the receipt of the next PRF pulse.

The shaft angle encoder also produces the algebraic sine and the cosine functions, which are transferred along with the binary code.

The continuously rotatable precision potentiometer converts the shaft angle, representing the radar antenna azimuth angle, into a bipolar linear-ramp voltage, which varies between +10 and -10 volts. The differential generator is mechanically adjustable so that the output of the potentiometer is zero at the area of interest. The output of the potentiometer is extended to an analog comparator located on the servo deck where it is compared with a unipolar voltage. In the Off Center mode of operation, this unipolar voltage is equivalent to half the angular extent of the sector selected, which is a function of the range and PRF rate.

This unipolar voltage, which is fixed reference voltage, is developed through the use of trimpots whose selection is determined by the relay on the servo deck and which are manually controllable by switches on the control panel.

The analog comparator compares the two voltages, and when the variable voltage from the potentiometer is more positive than the reference voltage the comparison is a negative 3 volts corresponding to a logical zero. When

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the potentiometer output voltage is more negative than the reference voltage, the comparator output is a negative 11 volts. A level-changing amplifier is added to the output of the comparator to make its logic levels correspond with these utilized throughout the equipment. When the level-charging amplifier has a logical "1" as its output, the "start" flip-flop (not shown) is reset to its false state. This allows the next PRF pulse to pass through the start azimuth gate and signifies the start, in azimuth, of the region of interest. This signal is utilized to generate the necessary signals such as Start Process, Master Reset, and Display Erase (in mode programmer units). The PRF pulse that passed through the AND gate is also used to set the Start azimuth flip-flop to its true state and thereby disabling the AND gate so as not to allow more PRF pulses through until the next time the comparator triggers.

The equipment is also provided with an auto-manual switch so as to allow cloud intensity values to be printed on the storage CRT and remain stored until erased by depressing the erase button. When the switch is in the AUTO position, the circuits that generate the master reset, display erase, and start process operate in accordance to that described above. However, in the manual position, the above three signals are controlled by a manual recycle gate. When the recycle button is depressed, the manual recycle flip-flop is set and a logical "1" resets the manual recycle gate. When the comparator triggers at the beginning of the antenna cycle, the PRF pulse from the "Start Azimuth" gate is gated through the manual recycle gate and on to the circuit that generates the three processing signals.

Address Circuitry

The function of the address circuitry is to provide the proper codes for handling the processed data that enter and are retrieved from the magnetic core memory. In the PPI mode, the address circuitry also functions as a real-time coordinate converter.

An address, as applied to memory operation, is simply a binary code of 10 bits. However, it is convenient in this design to divide the total 10-bit address into 5-bit (X and Y) components because of the rectangularity of the APMI display. It is also convenient to discuss the functioning of the address circuitry as a set of related but distinct sources. For an example, the X_1, Y_1 address circuitry generates the code necessary to place the average intensity data in the proper memory location. During subsequent read-out and printing, the numerical characters will appear on the display storage CRT in the correct location as detected. There are four sets of address. Figure 12 lists the purpose and use of each set.

Figure 13 shows the X_1, Y_1 address generator. It is apparent from this diagram that this circuitry is very closely associated with the coordinate conversion equipment.

In the PPI mode of operation, the scaler scales the rate of "carries" from the adder so that the least significant bit of the address corresponds to one display interval. However, in the Off Center mode of operation, the X_1 counter counts advance pulses generated by the processing programmer circuitry. This pulse occurs at the end of the "Print" interval, once each

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| | INTEGRATE | | STORE INTENSITY | | | | STORE DIMENSION | PRINT |
| | PPI | OC | PPI | | OC | | PPI/OC | PPI/OC |
	READ/WRITE	READ/WRITE	READ/WRITE	READ	READ/WRITE	READ	READ/WRITE	READ/WRITE
X	X_2	X_2	X_1	X_2	X_1	X_2	X_4	X_3
Y	FIXED AT 31	FIXED AT 31	Y_1	FIXED AT 31	Y_1	FIXED AT 31	Y_4	Y_3

Figure 12 — Memory Address Source Schedule

FIGURE 13 - $\underline{X}_1$, $\underline{Y}_1$ ADDRESS GENERATORS

RANGE SCALE	NORMAL	EXPANDED
25	2	1
75	6	2
200	16	4
450	34	6

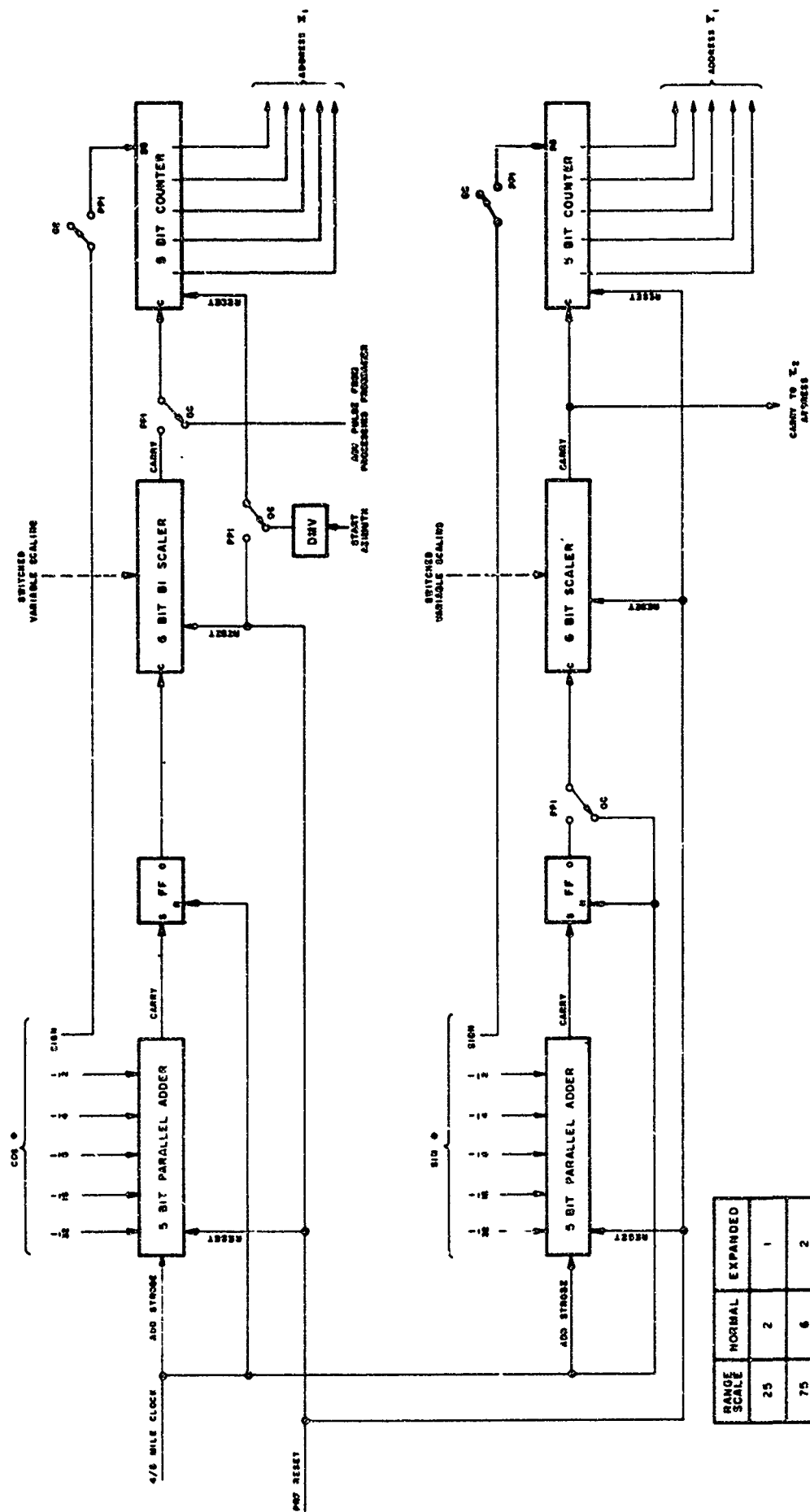SCALING FACTORS

processing cycle, so that the angular change in antenna position during the processing cycle is made equivalent to one display increment, in the X dimension, of the B-scan presentation.

The Y_1 address in the Off Center mode is generated by counting 4/5 mile clock pulses that have been scaled suitably to match the selected range with the B-scale Y dimension format.

Address X_2 (Fig. 14) is generated by a 5-bit binary counter arranged to count scaled 4/5-mile pulses generated from the X_1, Y_1 circuitry. Y_2 (not shown) is fixed at value 31 because this is the section of memory reserved for storage during integration. In the 25-mile range, the gating circuits adjust the least significant bit of X_2 by selecting alternate range increments or adjacent sweeps in order to reduce memory speed requirements. The output of the gate circuitry produces a pulse each time the address increases by one count. This pulse serves as an intensity readout command.

The X_3, Y_3 addresses function is to read from the memory during the print operation. This is accomplished by using two 5-bit counters connected in tandem. A closed-loop timing circuit generates pulses to advance the counters and also to command the various memory functions. The operation of the X_3, Y_3 is as follows:

a. The print ID bit is sampled, and if this bit is a "1," the word of that particular address has already been printed and therefore the word is returned to storage and a pulse sent to the X_3 counter. This action is continued automatically. In the case where the sampled printed ID bit is a zero, a Print Enable command pulse is generated, which calls for the data to be displayed. The address is maintained for 100 microseconds, the time required to accomplish the writing on the CRT display tube. The set ID bit command pulse, not shown in the sampling circuitry, causes a word to be written into storage when the Print ID bit is a "1."

b. The above action continues for the duration of each print interval. Eventually, all characters in the storage will be displayed. Code 31 of the Y_3 address is by-passed because no characters to be printed are stored in this section of the memory.

The X_4 and Y_4 memory addressing code is used to address the display portion of the memory at the time that dimension data are stored. The X_4 address is held in a 5-bit binary which is preset, at the time a range or azimuth dimension is made, with the X_1 address. This register is necessary because the X_1 code is continually changing, in addition to the fact that dimension code consists of three words, necessitating a two-step increase in the address before prestorage can be completed. The Y_4 address is preset into a 5-bit flip-flop register and remains constant until the three words have been stored.

The four different address sources (Fig. 15) are gated to the memory register at the proper times. The AR strobe is generated by the memory-timing control circuitry and functions to transfer the address code appearing on the input line into the memory address register. The lines are double-ended to avoid ever having to preset the memory address register.
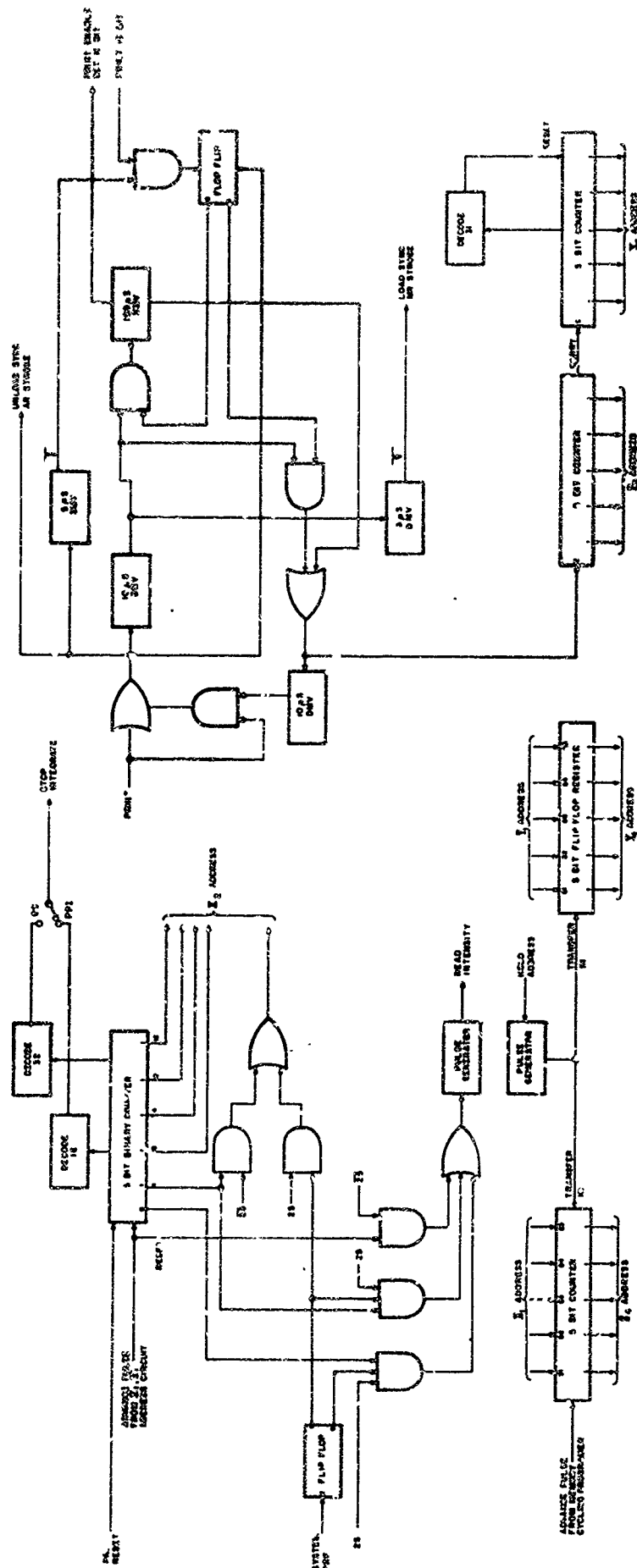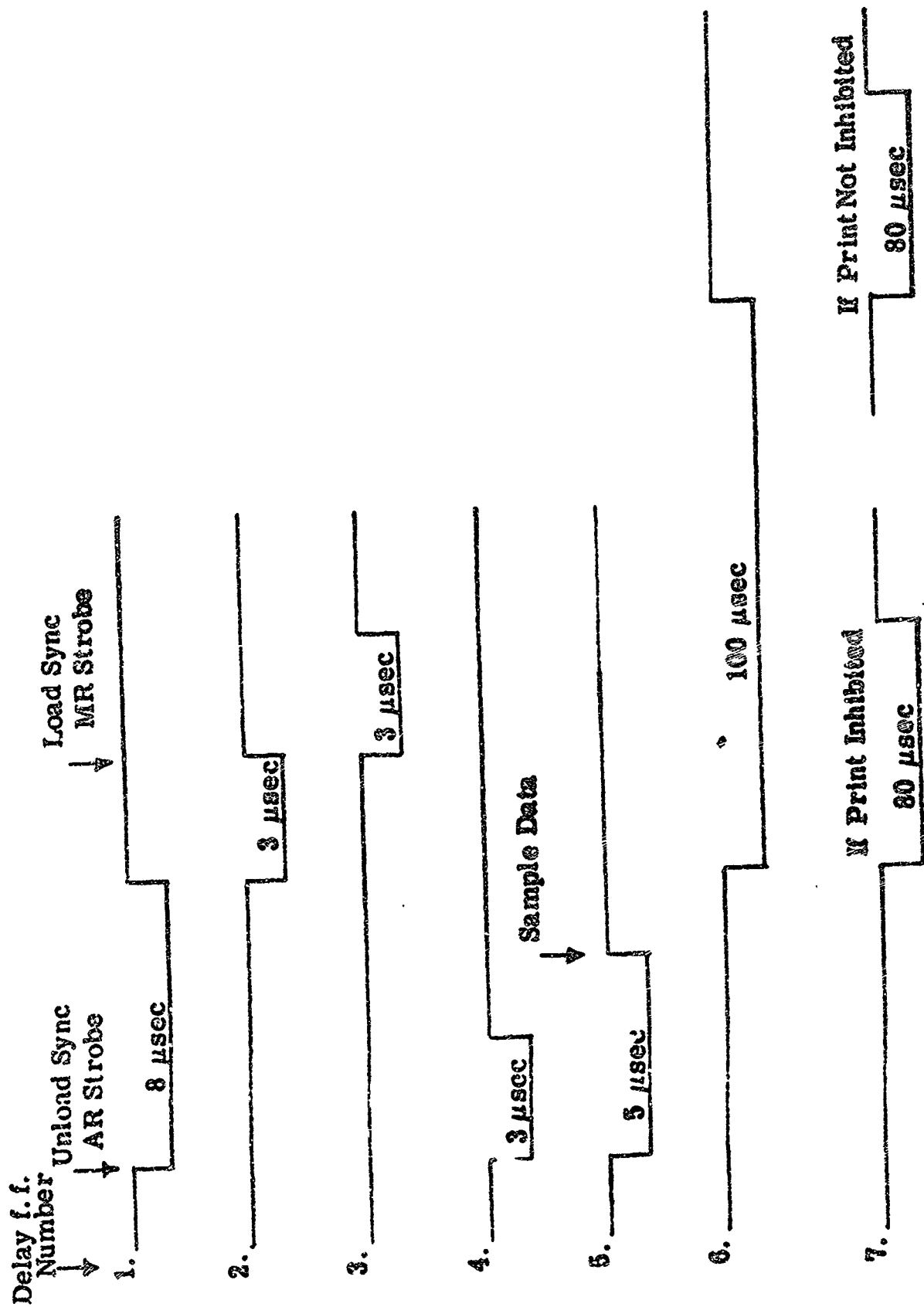
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FIGURE 14 - X_2 Y_2 X_1Y_1 ADDRESS CIRCUITRY

Figure 15. $\underline{Y}_3$, $\underline{Y}_2$ Address Timing

Delay f.f.
Number

Unload Sync
AR Strobe

Load Sync
MR Strobe

1.   8 μsec

2.   3 μsec

3.   3 μsec

4.   3 μsec

Sample Data

5.   5 μsec

6.   100 μsec

7.   If Print Inhibited
      80 μsec

If Print Not Inhibited
80 μsec

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Master Clock

The master clock consists of a 931.200-mc crystal-controlled oscillator and is utilized in the system to provide synchronized clock pulses at a rate equivalent to 1/5, 2/5, 4/5, and one radar mile. The circuitry also generates the system PRF pulses of sufficient length and delay to reset counters, shift registers, and flip-flop registers. (See Fig. 16, Master Clock Timing.) This delay is to compensate for the propagation delay that occurs from stage to stage throughout the equipment.

The frequency of 931.200 kc is used to generate the 1/5 mile clock pulses. The 2/5, 4/5, and one-mile rates are obtained by dividing the base rate through the use of flip-flop registers.

The unit also generates three PRF pulses: synchronized radar PRF, system PRF, and PRF reset.

Range Offset Circuitry

The range offset circuitry provides the range delay in the off-center mode of operation to place any radar target in the center of the display storage CRT.

The 9-bit binary counter, Fig. 17, counts the necessary number of one-mile clock pulses required to obtain the maximum range offset. A digital-to-analog converter converts the binary range count into its equivalent analog voltage.

The output of the digital-to-analog circuitry is extended to an input of an analog comparator via an operational amplifier. The leads of a multi-turn precision potentiometer, located on the control panel, are also extended to an input of the comparator. The center top of this precision potentiometer is used as a unipolar reference voltage for voltage comparison. The analog comparator receives both the potentiometer's reference voltage representing the desired range for offset operation and the analog equivalent of the range center representing radar range. When both voltages are coincident, the output of the comparator swings negative, triggering a delay flip-flop. This output is used to start the processing cycle. Also in this sub-assembly are circuits that generate a reset pulse used to reset the range counter.

Buffer Memory

The buffer memory is a random-access magnetic core memory (commercial design), with a memory capacity of 1024 words of eight bits each. The 1024-word requirement is because of the 32 x 31 sideplay format. The word length of eight bits is necessary because as many as 16 video intensity samplers are to be averaged.

An Ampex RB 1024 x 8 magnetic core memory provides the buffering action necessary to match the high data input rate of this system to the low character printing rate. It also serves to hold the intermediate sums during integration process. Thirty-two words (8 bits each) are reserved for

Radar PRF

5 u sec Delay
1 output

PRF Reset

Sync Flip-flop
1 output

System PRF

3 u sec Delay
1 output

Synchronized
Radar PRF

Time T_1 = 465.6 KC Clock Start
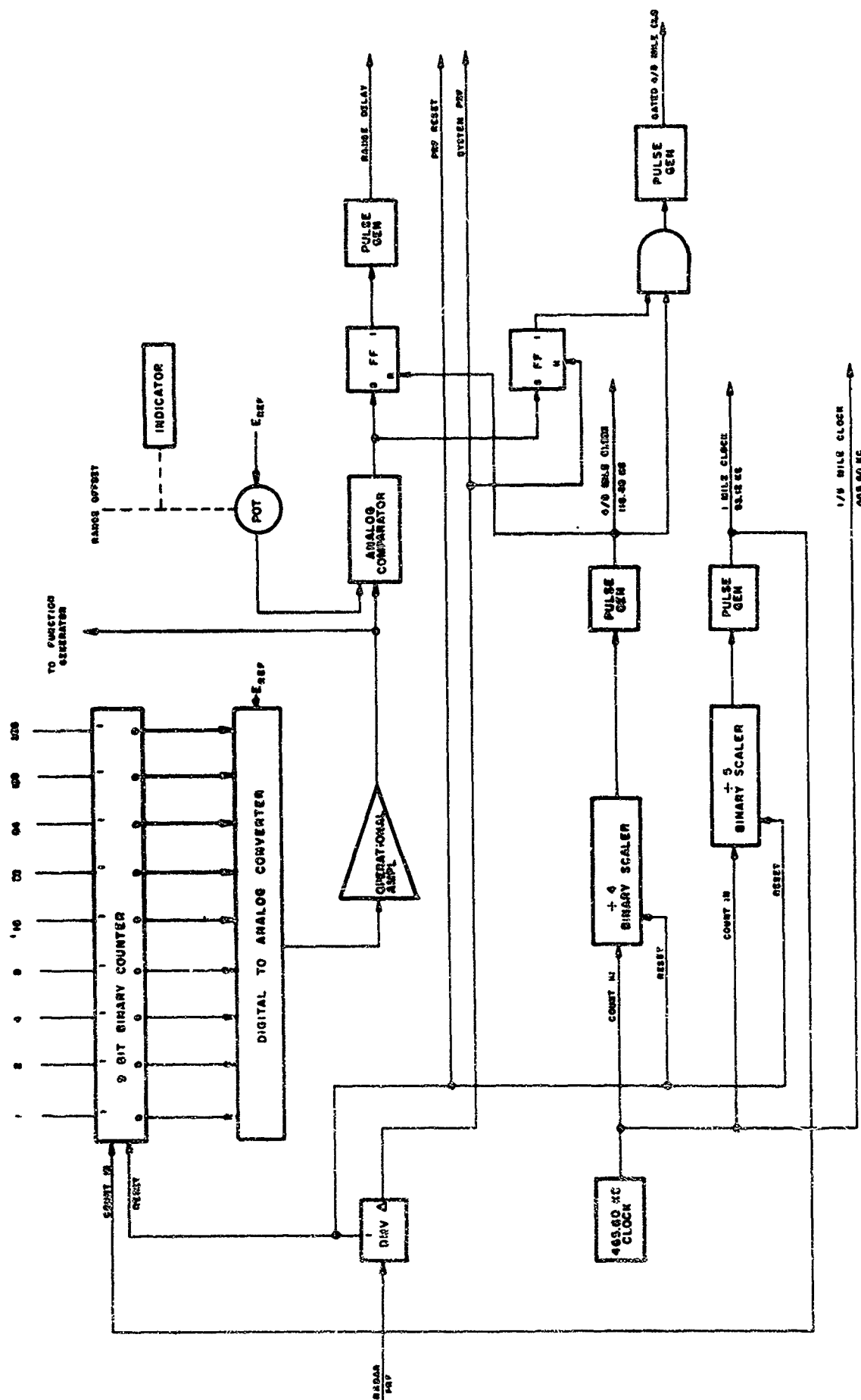
Figure 16 – Master Clock Timing

FIGURE 17 - RANGE OFFSET CIRCUITRY AND MASTER SYNCHRONIZER

integration, and the remaining 992 words are used to store data after processing and prior to display.

The memory is capable of completing a read or write action in five microseconds.

Detection and Range-Extent Measurement

The circuitry for the unit that performs target detection and range-extent measurement is shown in Fig. 18. Storage within this processor for commands, processing, and "hold" for readout is provided by transistor bistable registers employing binary digits. The radar video is one of the inputs to the detector which compares the video level to a threshold. The output is a binary "1" whenever the threshold is exceeded, and "zero" elsewhere. The detection circuitry decides whether or not a target exists and then measures the range extent of the target signal. If the target has a range extent of one mile or greater, an extent measurement will be made. The processor detects the extended target region and verifies the detection in range.

The output of the detector is sampled at the range clock rate of 931.200 kc, giving 1/5-mile resolution. If the signal has exceeded the threshold, the range clock and the detector output generates a "hit"; otherwise a "miss" is generated at the range clock rate. The requirement for a valid target is three hits in succession. To assure that the hits are consecutive, a miss is used to reset the target "start" counter. To prevent reset after the target start condition has been rendered, the miss signal is inhibited by the "0" output of the target start control flip-flop.

When the target start criterion has been fulfilled by three consecutive hits, the start flip-flop is "set" and transfers the range clock pulses into a three-bit counter. The output of the counter is decoded and is used to reset the counter on each five counts. This reset pulse occurs every mile, and successive five counts are accumulated in the BCD counters. This process continues until the target "end" condition is detected by a two-stage counter into which "misses" are applied as the count. To prevent false end conditions, this counter is reset by the "hit" condition.

The count-of-three decoder on the end condition counter is used to reset the start flip-flop which stops further accumulation of count in the 3-bit and BCD counters. It further controls processing, if the target exceeds one mile in range, by "setting" the second control flip-flop, which inhibits the start of the second target until the range-extent information has been read out. Occurrence of the proper end condition then allows the target range extent to be read out.

There is a control flip-flop which is set by the count of five outputs from the three-bit counter. If the range extent is one mile or greater, this flip-flop is set and allows the end condition and subsequent target extent readout. If the end condition occurs before the target extent has reached one mile, the setting of the end flip-flop is inhibited and the three-bit counter is reset and ready for the next target.
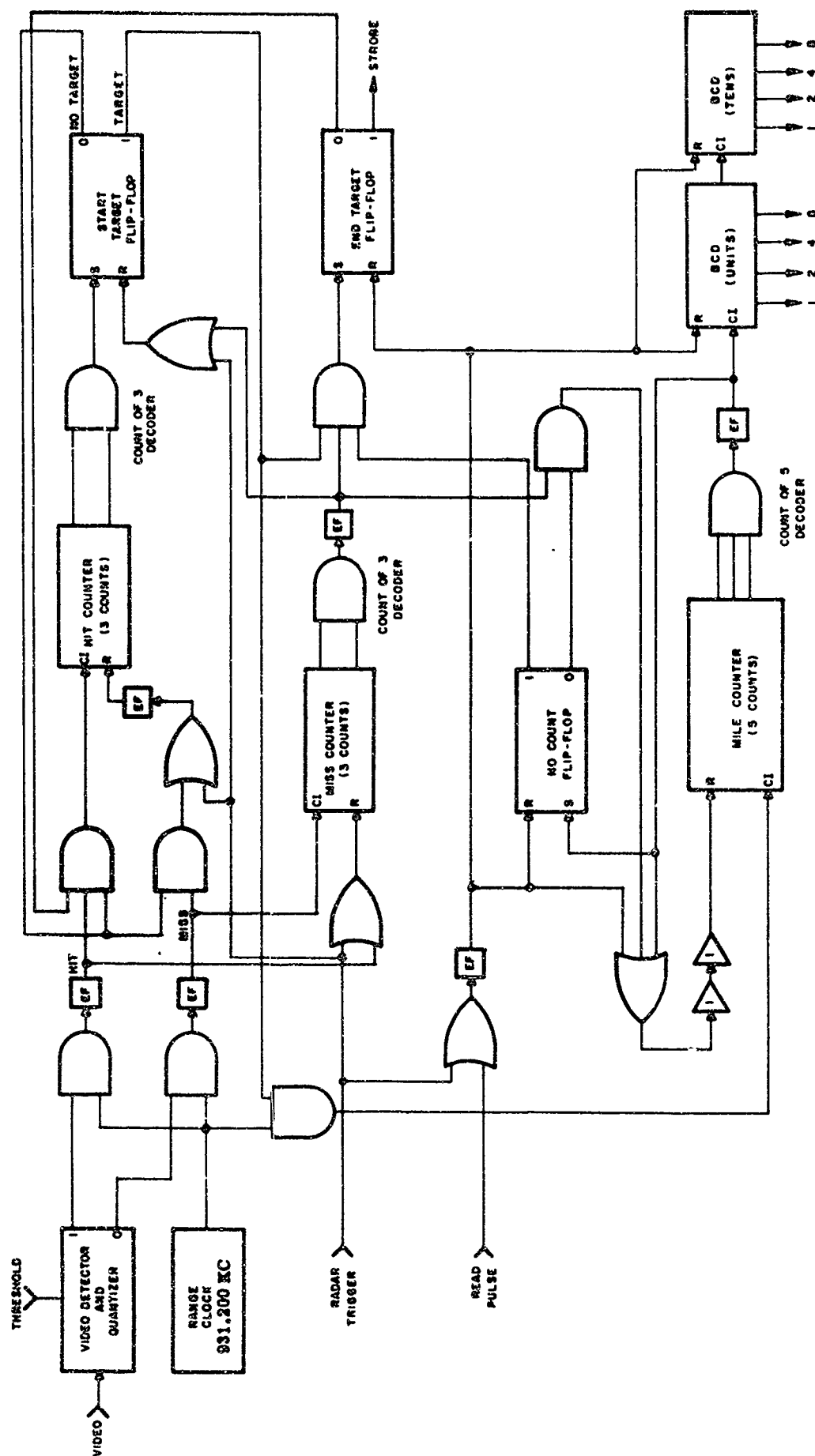
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FIGURE 18 - DETECTION AND RANGE EXTENT PROCESSOR

The expected operation for the detection of an extended target with range extent one mile or greater concludes with the range extent in the BCD counter and the end flip-flop, indicating the end of the target and calling for readout through the target strobe signal. The readout pulse then resets the necessary portions of the processor in preparation for the next target. In the case where no readout pulse occurs, or when there is a target in process at the radar's range extreme which cannot be completed, the radar trigger is used to reset the processor at the beginning of the radar sweep.

Azimuth Extent Measurement

1. _Azimuth Extent Counters_. Because information is generated discontinuously with time, a set of memory elements must be provided for each desired azimuth channel. Sixteen channels are provided in the Area Precipitation Measuring Indicator (APMI). This number is equal to the number of display elements in the PPI mode. In OFF CENTER operation, alternate display elements are processed for azimuth extent.

The azimuth-extent counters (Fig. 19) function as follows: A 17-bit shift register is driven by READ INTENSITY command which causes a bit to be shifted along the shift register in synchronism with the occurrence of individual display elements. The presence of this bit causes the input of the 16 binary counters to be operated in sequence. If a signal is detected anywhere within a display interval, the hit line will be energized, causing the input flip-flop to be set. The flip-flop, while set, allows azimuth change pulses (ACP) to pass to the count input of an 8-binary counter. The counter will accumulate a count at the ACP rate until a no-hit condition occurs, signifying the end of a target in the azimuth dimension. The no-hit signal resets the input flip-flop, stopping the counting process and causing a pulse generator to be triggered. The output of the pulse generator is extended to the multiplier unit as a start command and also transfers the accumulated count from the counter to an OR gate matrix and subsequently to the azimuth input of the multiplier. Although not indicated in Fig. 19, the 8-bit counter is also reset at this time.

Because the antenna is rotating at a constant 5 rpm, the ACP's are generated by a free-running multivibrator. A frequency of 34 cps is chosen to yield an angular change between pulses of 1/128 radian. The flip-flop operates to synchronize the ACP's with the PRF. This arrangement is permissible because the PRF rate is always greater than 34 cps.

2. _Multiplier_. Figure 20 gives details of the multiplier unit. Many of the operational details will be ignored in the following discussion.

The MULTIPLY START COMMAND initiates multiplication. The two quantities to be multiplied are the azimuth extent in radian measure, which is held in storage register A, and the range in miles, which is gated from the range delay counter into shift register D. Register B is a combination parallel adder and shift register. The contents of the A register are added to the contents of the B register under control of D bit. After each addition the partial produce sum in B and the contents of D are shifted one position to the right. This action repeats until the complete product is formed in
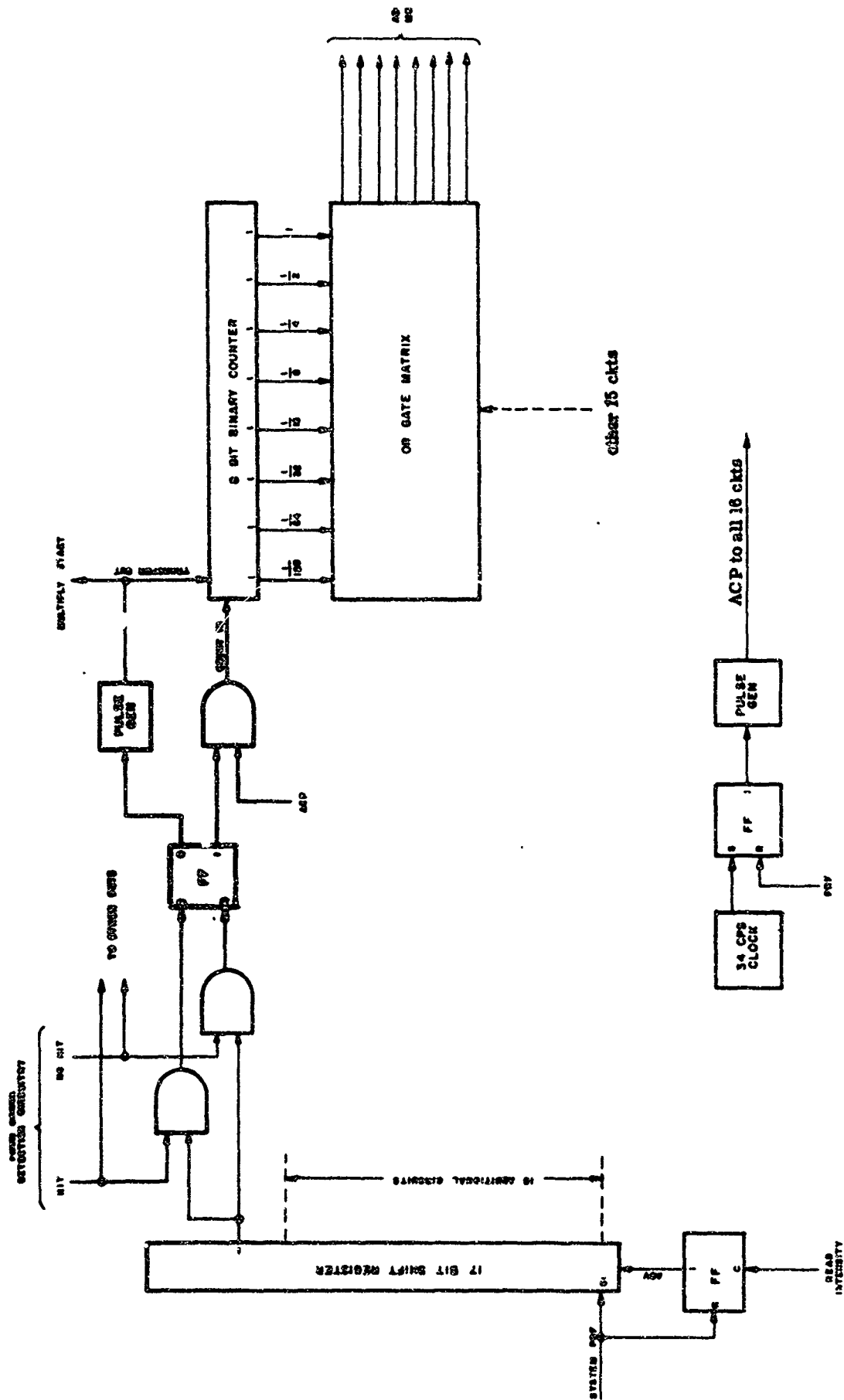
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FIGURE 19 — AZIMUTH EXTENT COUNTERS

registers B and D. The complement of 7 bits of the product is transferred in parallel to binary counter C. Counter C then accepts pulses at a 300-kc rate, as do the two BCD counters, until the count in C reaches zero. At this time the product, in natural binary form, will have been converted to the BCD code required for display.

The multiplication is accomplished in a maximum time of 100 microseconds. The OPERATION COMPLETE line is energized to signify that the product has been formed and is ready to be transferred to the display memory.

The operation concludes with a multiply RESET pulse generated in the dimension code receiver unit which stops the clock. Although not shown in Fig. 20, when the clock stops, the "zero" output of the clock's flip-flop goes "false" and triggers a delay flip-flop. This delay flip-flop generates a pulse that resets the adder, the azimuth register, the range register, the end of flip-flop, and the 75-kc divider.

Display

The display device (Fig. 21) is a 10-inch-diameter direct-view storage tube (Hughes Aircraft Company Tonotron Type H-1069AP20), with character display formed by an RMS Associates character generator. The basic format is a 32 (X) by 31 (Y) matrix.

When operating in the PPI mode, the corners of the display matrix are not used, thus decreasing the maximum number of characters that can be displayed. In the PPI mode of operation, the display element size in miles is as follows:

(a) Twenty-five miles, 1.6 miles on a side

(b) Seventy-five miles, 4.8 miles on a side

(c) Two hundred miles, 12.8 miles on a side

(d) Four hundred and fifty miles, 28.8 miles on a side

In the expanded mode of operation (a) is expanded 2:1; (b) 3:1; (c) 4:1; and (d) 6:1. In the expanded mode of operation, then, the display element size for (a) is 0.8 mi x 2.9°; (b) 1.6 mi x 1.6°; (c) 3.2 mi x 1.6°; and 4.8 mi x 1.6°. When in the expanded mode and operating on short pulse (931 PPI), (a) is 0.8 x 1.1°, and (b) is 1.6 x 0.58°.

The character spacing is 1/4 inch, and character size is on the order of 1/8 to 3/16 inch in both PPI and expanded mode of operation.

Electrical Test

Electrical tests were conducted on the AFMI to determine its capability under a planned set of test conditions.

A special test jig was constructed to simulate cloud dimension and echo intensity (see Fig. 22). This simulator device consisted of a cam-operated
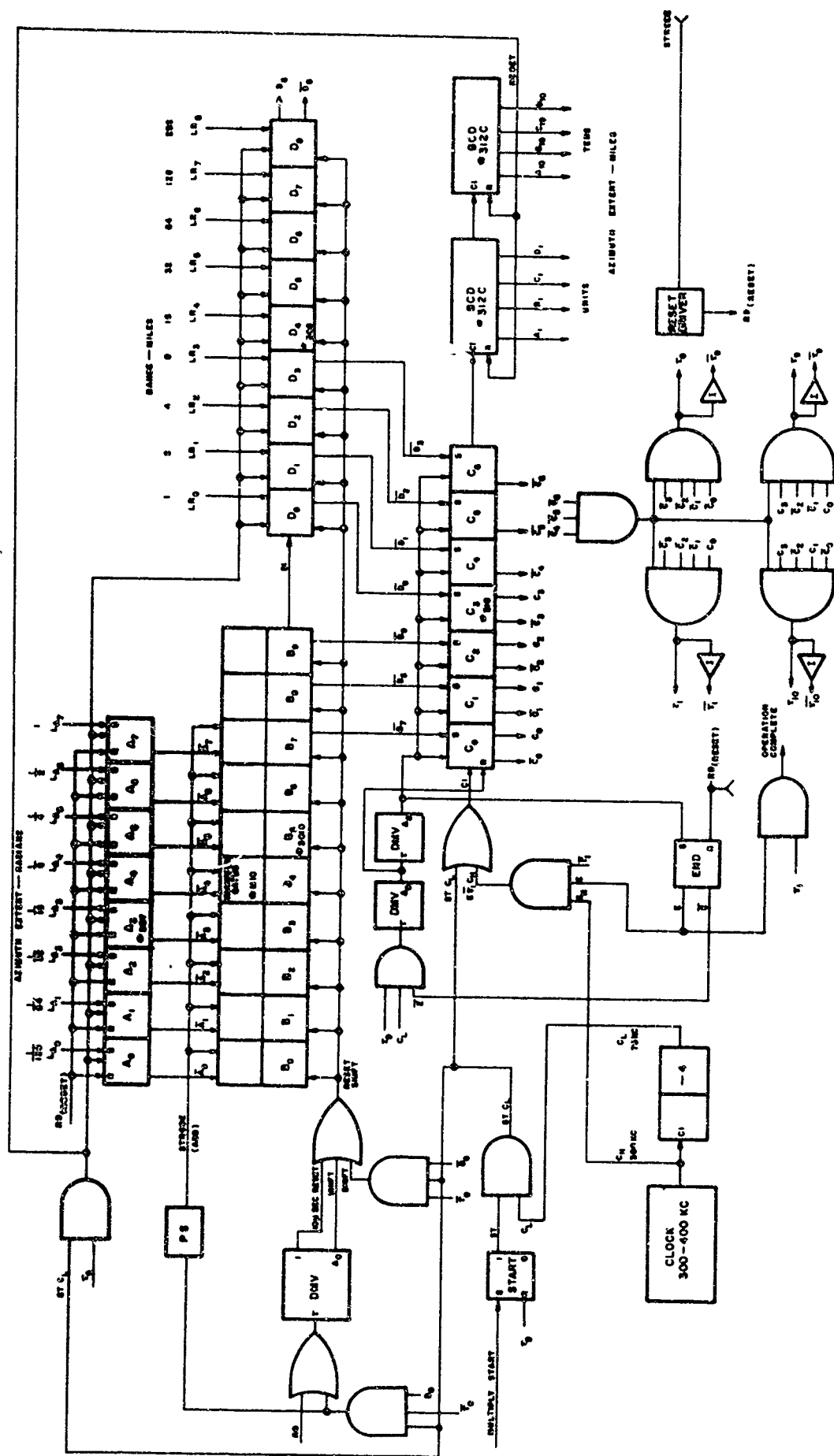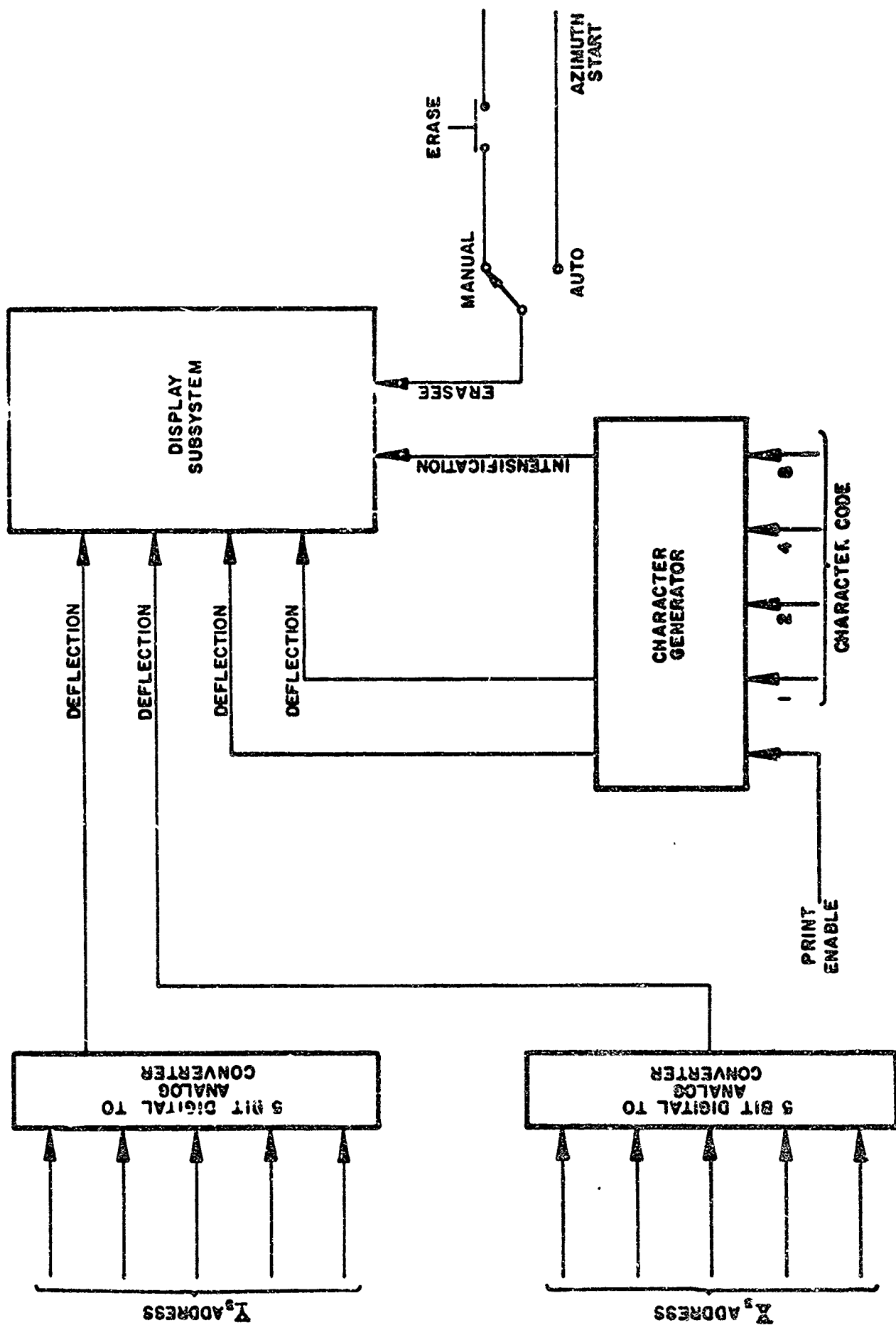
FIGURE 20 - MULTIPLIER UNIT
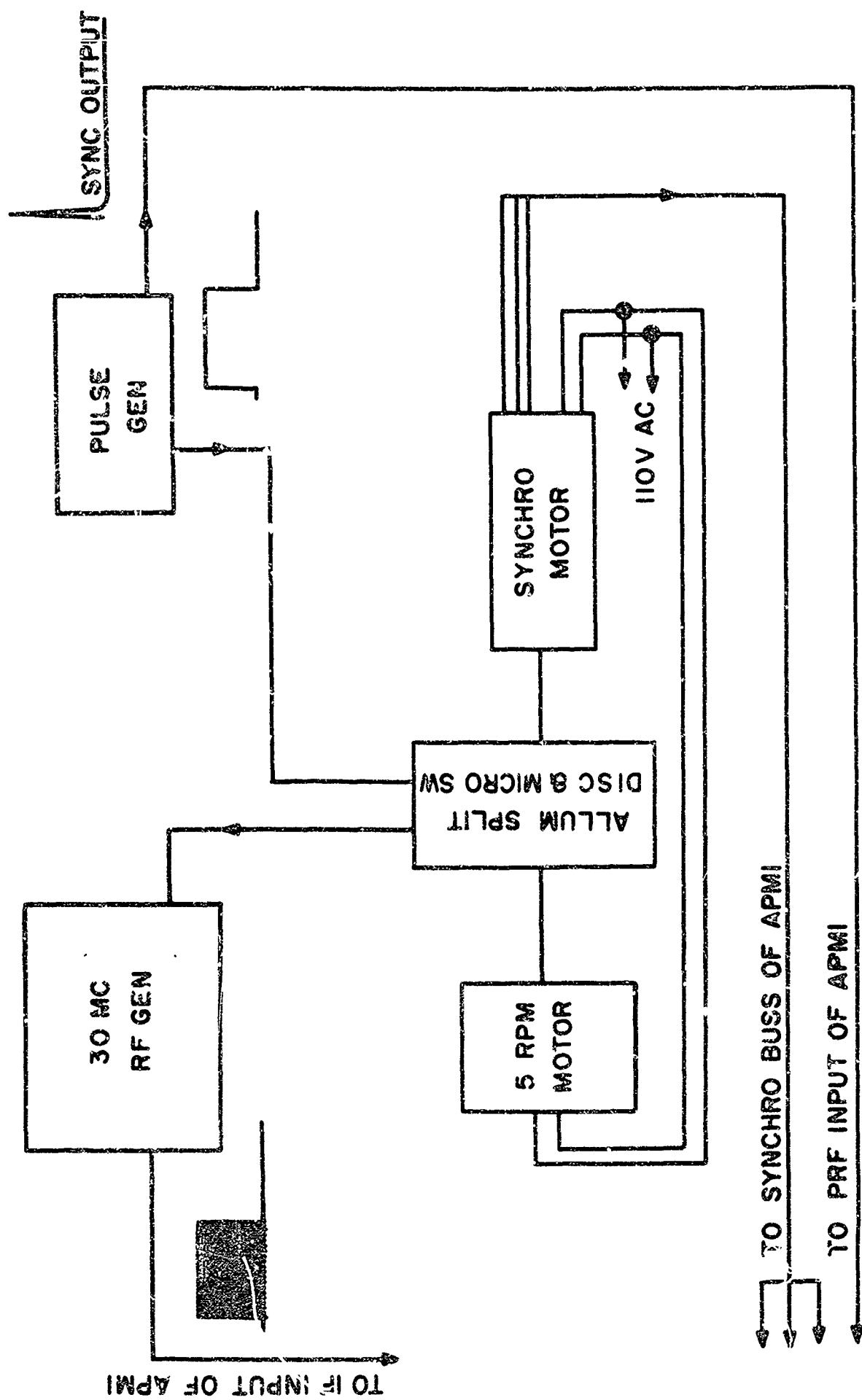
FIGURE 21 - DISPLAY CIRCUITRY

FIG. 22 TEST JIG

SYNC OUTPUT

PULSE GEN

30 MC RF GEN

ALLUM SPLIT DISC & MICRO SW

SYNCHRO MOTOR

110V AC

5 RPM MOTOR

TO IF INPUT OF APMI

TO SYNCHRO BUSS OF APMI

TO PRF INPUT OF APMI

switching device, RF generator, pulse generator, synchro motor and a 5-rpm synchronous motor. This hardware together with gears and axles was mounted on a test board, and the electrical output connected to the IF input of the APMI system. The shaft of the 5-rpm motor, through axles and gears, directly drives the synchro motor and a four-inch aluminum disc. The latter was constructed so that its gap could be adjusted from 0 to 180 degrees. (The gap opening determines the length of time the microswitch, activated by the disc, is activated.) The terminals of the synchro motor were connected in parallel with the synchro motor in the APMI. This arrangement permitted synchronism between the drive motor of the simulator and the APMI. The output of the pulse generator was connected to the pulse input of the 30-mc RF generator via the cam-operated MICO switch. Finally, the output of the RF generator was connected to the IF input of the APMI system.

The above-described setup in effect simulated various types of weather cloud of limited configuration. In general, though, this configuration is concentric in nature and can be varied in size and position in range and azimuth. With the aid of the attenuator pad on the RF generator, the amplitude could be varied so as to simulate the dynamic variations of echo intensities.

This test procedure presupposes that any set of simulated data would result in identical intensity, range, and azimuthal values displayed.

Figure 23 is a photograph of a simulated cloud image, in numerical form, occurring at the northeast sector of the display storage CRT. For this picture, the simulated input signal was distorted in a manner as to vary in magnitude in range extent of the cloud. The sweep range was 200 miles. Occurring on the outer periphery of the intensity levels are the range extent measurements, preceded by an "R." The azimuthal extent, not shown here, would appear at the lower periphery of the intensity levels, and would be preceded by an "A."

As explained in the "Intensity Measurement" paragraphs, a ten-level measurement of the incoming signal is performed. These measurements are made by limiting amplifier circuits which produce an output whenever a preset threshold is exceeded. The outputs are held in bistable digital circuits and decoded to obtain a binary coded decimal output. This output is averaged with additional intensity measurements over a number of successive sweeps prior to being displayed.

For this test the video gain was adjusted so that a 10-volt output signal corresponded to near saturation of the IF strap (approximately 50 milli-volts at the IF input terminal). Since a 10-level measurement can be performed, each level of the 10-volt signal corresponds to 7 db/volts. NOTE: The IF amplifier is logarithmic; therefore, equal output voltage corresponds to equal decibel increments of the input signal.

In actual practice, a 7-db spread for each energy level may be undesirable; however, for these experimental tests, this arrangement was considered suitable.
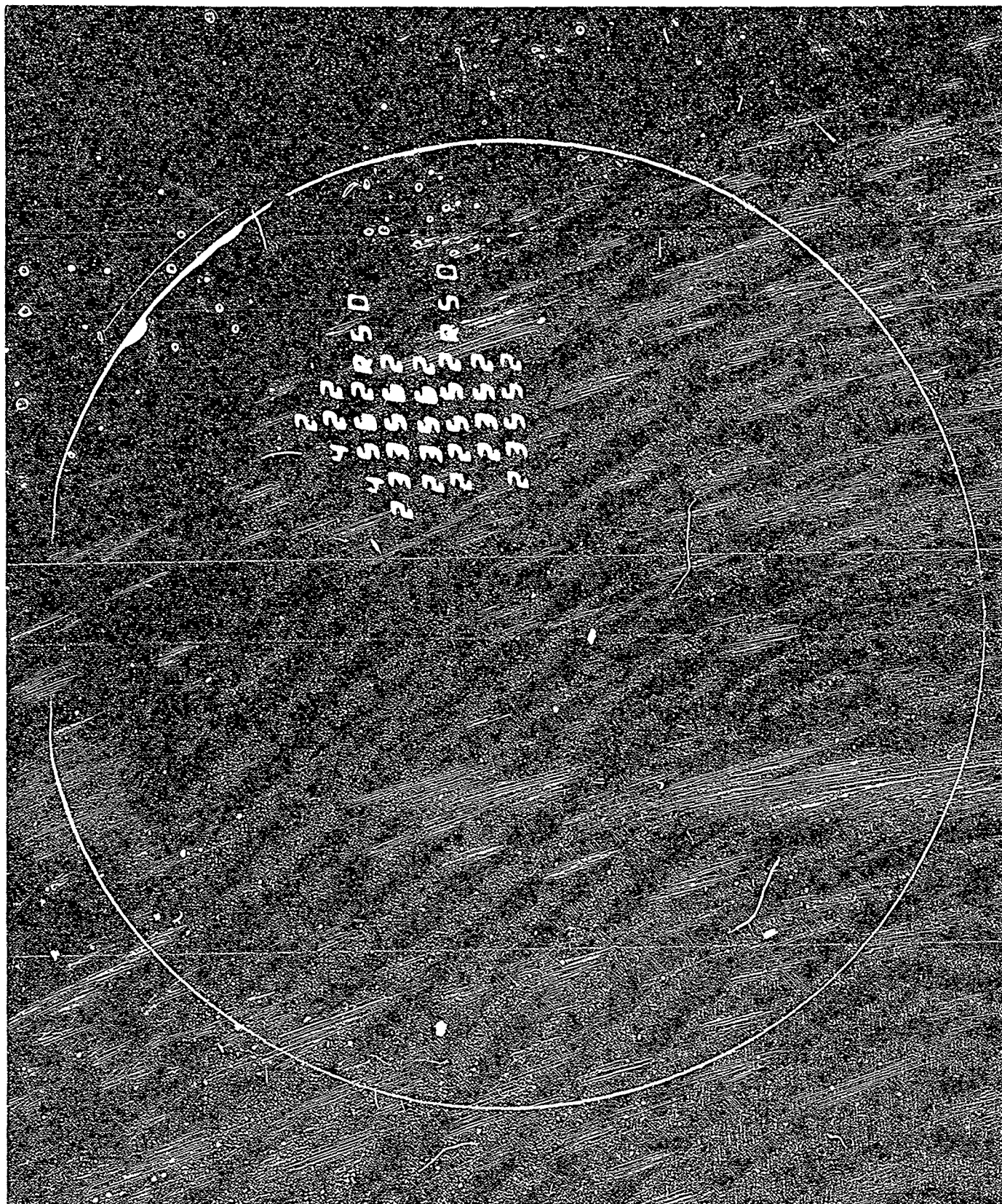
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Fig. 23. Simulated Cloud Image, in Numerical Form

The APMI system was then tested to determine its capability in accurately and consistently printing the correct numerical values with a calibrated input signal.

The four-inch aluminum disc was adjusted for minimum gap opening. This in effect activates the microswitch for 360 degrees rotation. The pulse generator was adjusted for maximum pulse width, with zero delay of the leading edge. The RF generator, which is pulsed by the pulse generator, was increased to a level which was on a fringe of saturation of the IF amplifier (approximately 50 millivolts).

Intensity

The APMI, with the setting as stated above, displayed "10's" over the useable area of the CRT tube. The RF generator was then attenuated in steps of 7 db and the output numerical values were viewed on the APMI storage tube. For each test case, the indicator displayed the correct numerical value.

Range

The above-described test setup was also used for checking the range and azimuthal measurement. However, for the range measurements, the lead edge of the signal from the pulse generator was delayed by a desired amount, and its pulse width was adjusted to represent steps of one mile extent (approximately 5.07 microseconds per mile). Care was taken to insure that the range extent did not exceed 99 miles, for this is the maximum computing capability of the system. Although not completely necessary for range extent measurements, the cam was adjusted so as to derive azimuthal dimensions.

This test was performed to check for repeatability of range measurement values with various azimuthal extent settings. In each test case, the range-extent numerical values displayed agreed with the calibration input signals. This was also true when the signal level was just above the noise level of the IF amplifier.

Azimuth

It is difficult to perform a good qualitative test of the functioning of the azimuthal extent. The reason is primarily because of the laborious job in accurately calibrating the gap setting of the aluminum disc and the delay caused by the ON-OFF reaction of the microswitch. Because of this adjustment problem, it was anticipated that a slight discrepancy would exist between the calibrated gap setting and the azimuthal extent values displayed.

The displayed extent measurement should equal a value computed by the equation

$$A = \frac{t}{s} \times 2 \pi R,$$

where

A = azimuth extent in miles,
t = zero volts portion of square wave in seconds,
s = time of one antenna rotation in seconds,
R = delay setting of simulated target in miles.

The calibration of the test jig for simulation of azimuthal extent signals was an anticipated test for this mode of operation; however, the azimuthal measurement circuits were inoperative when the equipment arrived at these Laboratories, probably due to damage of an electronic part during transportation. Therefore the system was not tested in this mode of operation.

All of the above-described tests were conducted without range normalization function applied to the sensitivity time control of the IF amplifier. If this function were applied, the intensity values displayed would have varied in range in accordance with the $\frac{1}{R^2}$ or $\frac{1}{R^4}$ law.

FUTURE SYSTEM CONSIDERATION

Consideration is being given to the use of this equipment as a radar rain gauge suitable for precipitation quantity measurement. In order to correlate rainfall rate with echo power, the radar transmitter and receiver must be extremely stable so that the received echo signals from rain can be measured accurately. However, these echo signals are highly statistical in nature and therefore require some form of time and space averaging of the intensity measurements to assure a good estimate of amplitude. In essence, the present system, by virtue of sweep-to-sweep averaging, satisfies the area integration requirement, but does not account for integration in time. It is felt that time integration is required because of signal fluctuation. This signal fluctuation may be attributed to the fact that raindrops are randomly distributed in phase, and these raindrops behave in an unpredictable manner throughout the illuminated volume. The varying spacing between droplets results in a decorrelation of signal with time.

Studies are presently being conducted and instruments have been constructed in an effort to solve the above-stated problem, but for the most part the solution has been directed toward a single illuminated volume of the cloud. If the equipment is to have operational flexibility, it should have a 360-degree antenna rotation time-integration capability. It is towards this end that these Laboratories are placing their effort.

It is recommended that space integration be performed over a complete square rather than that of the wedge-shaped area presently employed. This, in effect, will provide a uniform area display over the entire CRT.

Since it has been found through operating experience that the combination of intensity and dimension values tends to clutter and confuse the operator, it is recommended that this mode of operation be eliminated from future procurements. Surely, by the use of the radar range marker one can readily determine the radial dimension of a cloud. And similarly, knowing the range to the cloud, and with the aid of a simple hand calculator or conversion table, one can calculate the azimuthal dimension to the accuracy required.

CONCLUSIONS

Pulse-to-pulse averaging in the PPI mode is accomplished by adding data from eight consecutive sweeps when using the low PRF (186 PPS), and 16 consecutive sweeps when using the high PRF (931 PPS). Eight sweeps are equivalent to 1.29 degrees of antenna rotation, and 16 are equivalent to 0.515 degree. The display element size in miles is 1.6, 4.8, 12.8, and 28.8, depending on the expansion ratio of the display (25, 75, 200, and 450 miles).

Since the display elements appear to be rectangular, one will assume, without referring to the design criteria, that the number displayed is an average over a complete square. This, of course, is not true because the machine averages the same number of sweeps regardless of the range to the target. Therefore, the numerical value displayed represents a wedge-shaped area whose azimuthal dimension varies in direct proportion to the range. This, in effect, ignores a vast amount of radar data from targets at close-in ranges and inherently, because of the nature of this type of sweep, will return less data from distant targets. Obviously, the equipment does not compensate for this deficiency; therefore the operator must bear in mind that the integrated area size does vary with the radar range.

As stated in the "Electrical Test" paragraphs of this report, the azimuthal dimension mode of the system was inoperative, but making it operative is just a matter of locating and replacing the defective electronic part. This will be accomplished after the publishing of this report.

Mounted on the front panel of the display console is a four-position switch which permits the operator to select the print-out of either the signal intensity, range measurement, azimuthal measurement, or all three. When in the ALL position, the CRT tends to become cluttered and confusing even though each extent value is preceded by an identifying symbol. Also, when the three types of data are called for, some of the intensity values are discarded because dimension data have printing priority over intensity data. Since the principal interest is in intensity data, the practice has been to operate in the intensity mode and switch to dimension mode on the next antenna rotation or whenever the dimension of a cloud is of interest.

The Area Precipitation Cloud Measurement Indicator, designed and constructed by Motorola, Inc., meets all of the requirements of the specification and has proved to be a reliable and easily adjustable instrument. The equipment was operated in the environment in which it was intended (dynamic); however, this operation was without knowledge of the output power of the radar set. This power output calibration is necessary in order to accurately determine the echo power.

Figures 2, 4, 5, 6, 10, 12, 13, and 21 were extracted from Report No. RLS-3875-1, "Design Plan for an Automatic Cloud-Measuring Indicator," Motorola, Inc., September 1962.

Figures 7, 8, 9, 15, and 16 were extracted from Final Report No. 12, "Automatic Cloud-Measuring Indicator," Motorola, Inc., July 1963.